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Supreme Court of the United States

OCTOBER TERM, 1930

No. 12, Original

THE STATE OF CONNECTICUT, COMPLAINANT
v.
THE COMMONWEALTH OF MASSACHUSETTS, DEFENDANT

IN EQUITY

JOINT SUMMARY OF EVIDENCE

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STATEMENT WITH RESPECT TO THE SUMMARY OF THE EVIDENCE

This joint Abstract of portions of the record, submitted by counsel for both parties, is designed to summarize within a reasonably small compass the evidence introduced upon issues on which The Special Master has made findings, to which the Complainant has taken exception. Both parties desire to reserve the right, for the purpose of amplifying this summary, to refer specifically in briefs and in argument to original exhibits and to the original transcript of the evidence, even though such exhibits or such portions of the evidence are omitted from this Summary by inadvertence or for the purpose of condensing the record.

STATISTICAL DATA

The following statistical data has been agreed upon by both Connecticut and Massachusetts.

Watershed of Connecticut River tributary to river at Massachusetts-Connecticut state line near Thompsonville (Transcript p. 111, Exhibit D-4; see Exhibit C-9) 9,722 sq. miles

Drainage area Connecticut River watershed in Connecticut (by substracting 9,915 from 11,300) 1,385 sq. miles

Total drainage area of Ware River (Bill, p. 5; Transcript p. 131) 221 sq. miles.

Drainage area of Ware River at point of diversion (Reprint of answer, p. 11; Transcript, p. 131, Exhibits D-4, C-9) 98 sq. miles.

Total drainage area of Swift River (Bill, p. 5; Transcript p. 131) 213 sq. miles.

Drainage area of Swift River at point of diversion (Reprint of Answer, pp. 21, 85; Transcript, p. 131, Exhibits, D-4, C-9) 186 sq. miles.

Drainage area of Swift River at Bondsville (Reprint of Answer p. 93; Transcript, pp. 105, 132) 195 sq. miles.

Population of cities and towns in the Metropolitan District now actually using water from the Metropolitan supply (1928 estimate, Transcript, pp. 175, 176) 1,465,740

Population of Metropolitan Area about Boston (including all cities and towns entitled to join the Metropolitan District. Transcript, p. 133; Reprint of Answer, pp. 19, 20, 21) 1,900,000

Population of Connecticut in 1925. (U. S. Bureau of the Census, 14th Census, 1920, vol. 1, p. 20; Transcript, p. 133) 1,380,631

Population of Connecticut in 1928. (U. S. Bureau of Foreign and Domestic Commerce. Statistical Abstract of the United States, 1929, p. 7; annual midyear estimates by States, Trans. p. 133) 1,667,000.

The total drainage area of the two rivers subject to diversion is 2.93% of the total watershed of the Connecticut River above the state line. (Ware River, 1.01%; Swift River, 1.92%; Transcript, pp. 139,140)

The mean annual discharge of the Connecticut River at the Massachusetts-Connecticut state line is 17,000 cubic feet per second. (Transcript pp. 137, 656)

The average net diversion from both the Ware and Swift Rivers under the War Department's restrictions is 2 per cent of the mean annual discharge of the Connecticut River at the Massachusetts-Connecticut state line. (Transcript pp. 1417-1418, 656)

Total amount of stored water to be released from the Swift River Reservoir under the War Department restrictions which would actually increase the flow which would otherwise exist in the Connecticut River would average about 146 million cubic feet per year or .03% of the average annual flow of the Connecticut River at the state line. (Transcript, p. 1420).

MASSACHUSETTS LEGISLATIVE REPORTS

Three reports of the Massachusetts legislature were introduced in evidence, viz:—

House Document 500 (1895)—Exhibit C-3
House Document 1550 (1922)—Exhibit C-1
House Document 900 (1925)—Exhibit C-2

Copies of these reports are on file with the Clerk of this Court. Counsel for either side may in their briefs summarize these reports or quote from portions thereof, if necessary, upon the argument of the Complainant's exceptions to The Report of The Special Master.

It is agreed that the Reprint of the Answer contains true copies of the Massachusetts legislation (St. 1926, c. 375 and St. 1927, c. 321); true copies of the correspondence (therein quoted) between The Metropolitan District Water Supply Commission and various officials of the War Department; and true copies of the War Department findings. These documents were introduced in evidence.

PHYSICAL CHARACTERISTICS AND INTERPRETATIONS THEREOF

DR. FRANK E. WINSOR, Chief Engineer of the Metropolitan District Water Supply Commission, testified (89, 197) that the tunnel now under construction between the Wachusett Reservoir and Coldbrook on the Ware River, is of horseshoe shape 12 feet 9 inches by 11 feet wide, having a cross section equivalent to the area of a circle with an internal diameter of 12 feet 9 inches; that the tunnel is entirely through rock, and is to be lined throughout with concrete; that legislation under which the work is being carried on contemplates no storage of water on the Ware River and no diversion of water except when the flow in the Ware River exceeds 85 million gallons a day from 98 square miles, quite a moderate flow and about the flow ordinarily developed for the use of mill wheels on the Ware River; that the Massachusetts legislation contemplates extending the tunnel from the Ware River to the Swift River, some 10½ miles further and building a reservoir in the valley of the Swift River by the erection of two dams, one on the main stream and one on the side of the proposed reservoir where the ground is too low to hold the water in the reservoir; that the Swift River reservoir will serve not only to store Swift River water but also surplus Ware River water; that the capacity of the tunnel already built will be about 900,000,000 and some odd gallons a day, and assuming that the tunnel from Coldbrook to the Swift River is built the same size, its capacity will be about the same, under most favorable conditions, which depend upon head or pressure actually effective; that inasmuch as the point of diversion on the Ware River is higher than either the Wachusett reservoir or the proposed Swift River reservoir, water can be diverted in either direction from the Ware; (197) that if water were being diverted from the Ware River in both directions (i. e. both to the Wachusett Reservoir and to the proposed Swift River reservoir) the total maximum capacity of the two tunnels to divert Ware River water only would be 1,900 million gallons a day; that the tunnel, both so far as already built,

and if completed through to the Swift River at the same size, might not be large enough to take care of the flow which might be sent through it under the following circumstances; (1) when there is as high a flood on the Ware as might reasonably be expected in the light of the records of floods since 1913, and of a flood on the Nashua River of 9600 cubic feet per second in 1898, (691) (Dr. Winsor testified, however, that since 1913 there has been no flood on the Ware too large for the tunnel to handle); (691) (2) when the Wachusett Reservoir is full and it is desired to send Ware River water to the Swift River Reservoir to be stored at times of very high water on the Ware River watershed; (3) when the Wachusett Reservoir has been drawn down to a very low point for cleaning or repairs and it is desired to send large quantities of water through the tunnel from the Swift River Reservoir in order to fill the Wachusett Reservoir rapidly; that the diversion dam at Coldbrook that is being designed to divert the flood flow of the Ware River into the Wachusett aqueduct is designed large enough so that the spillway will carry 20,000 second feet safely without injury to the dam; that if there were a flood of half that, nowhere near that amount could be taken through the tunnel in both directions; (211) that the spillway has been designed to take care of a greater quantity of water than the maximum flood records show has ever occurred there; that the tunnel has been designed to make sure that none of the Ware River waters get away; (693) that the Massachusetts legislation authorized the construction of a temporary diversion dam in the valley of the Swift River before the main reservoir is built or before time would permit its building; that the plan would involve extending the tunnel at the same gradient to the valley of the Swift River near Quabbin Lake in the town of Greenwich, where the tunnel would end; (694) that the drainage areas tributary to this tunnel at Quabbin Lake are small and it was found that the middle branch of the Swift River which comes down east of the Prescott peninsula could easily be forced back into Quabbin Lake by building a small diversion dam (which is the temporary diversion dam referred to in the act)

slightly below the junction of the East and Middle Branches of the Swift River, which would force the waters back into Quabbin Lake and thence into the tunnel; that water could be taken under this temporary diversion only at such times as the War Department permitted; that it has not yet been decided whether or not this temporary diversion will be undertaken; that it is a diversion which might not last more than four or five years and would enable the postponement of heavy expenditures on the big reservoir; (693) that during the time when the plan for the temporary diversion (authorized by Mass. St. 1927, c. 321, Sec. 1, Reprint of Answer, p. 52) of the waters of the East and Middle Branches of the Swift River is in force, the tunnel capacity will be taxed; that, inasmuch as there would be no storage back of the temporary diversion dam, in order to take all the water available during a freshet on the Swift River it must be taken while the freshet is still in progress and it is necessary to have tunnel capacity sufficient to send immediately all water diverted under the temporary scheme through the tunnel to the Wachusett Reservoir; that the diversion dam would be a very low one; (696) that the War Department has not yet passed upon the temporary diversion and no formal authorization has been issued by the War Department to erect the temporary dam; (697, 698) that about 18% of the time there would be more water available under the temporary diversion project than could be carried through the tunnel to the Wachusett Reservoir at times when floods from the Ware River had to be diverted at the same time, because during the continuance of the temporary diversion the tunnel from Coldbrook (on the Ware River) to the Wachusett Reservoir would have to carry the flood flows, not only of the Ware River, but also of the Swift River, as there would be no storage available for these waters except in the Wachusett Reservoir; that a tunnel of this size, he said, must have capacity sufficient for a considerable degree of elasticity in operation in order to take care of all contingencies which may arise; (686, 687, 690) that the tunnel is large enough to take care of additional water if in the future

the freshet flows of further tributaries of the Connecticut River are diverted, and that the possibility of taking such water in the future was one of the elements considered in the size of the tunnel, although the tunnel was designed primarily for the purposes of the Ware-Swift project alone; (687) that in his opinion a tunnel of one-half the capacity would cost only about 15% less, *i. e.* a smaller tunnel, having a diameter of 9 feet with one-half the capacity, would cost 85% of the price of the 12-foot 9 inch tunnel now under construction; (compare transcript pp. 1170, 1171). (18), (20), (700), (715) that the precise size of the Swift River Reservoir had not as yet been determined; (700), (702), that various reservoir capacities have been considered by the Commission, including one at elevation 500 feet above mean low water in Boston Harbor having a capacity of 215 billion gallons, one at elevation 515, having a capacity of 318 billion gallons, (717) one at elevation 530, having a capacity of 420 billion gallons; (700) that in his opinion a flow line between 500 and 515 would be the best height for the reservoir, as it provides at very moderate expense for exceedingly long time storage, and inasmuch as long time storage has been practically the main dependence for assuring pure water for the Metropolitan District of Boston for a generation (704) the additional cost of raising the flow line of the Swift River Reservoir from 500 feet to 515 feet of about $1,250,000 would be well expended, that the cost of raising the flow line of the reservoir from 515 feet to 530 feet would also be $1,250,000 (701) that these additional costs represent practically all the cost involved in raising the flow line, between the points indicated, including not only the cost of construction, but also the cost of additional real estate needed in raising the reservoir from 500 feet to 515 feet amounting to about $150,000 and (702) in raising the reservoir from 515 feet to 530 feet about $250,000;

(204, 206) that a very large amount of land not actually flooded, would have to be acquired, regardless of what the elevation of the flow line might be, because of the necessity

of protecting the drainage area of the reservoir from possible contamination; that surveys for a reservoir on the Swift River have been made and considerable property has been purchased; (17) that something over 35,000 acres of land, which is approximately 60% of what is contemplated being acquired for reservoir purposes, have been acquired; that he includes in reservoir purposes such land as is deemed essential to provide for the sanitary protection of the reservoir,—that is, the marginal strip around the reservoir; (205) that the total amount which may be acquired for reservoir purposes is about 60,000 acres which is practically 90 square miles;—that that includes large areas outside of the reservoir (206) for the protection of the purity of the water; (204) that the elevation shown on Exhibit D-1 for the maximum flow line which has ever been considered for this reservoir is about 530 ft. above sea level; (206) that at that elevation the reservoir will occupy probably 39 square miles; (204, 205) that the fact that the large number of peninsulas (particularly the large Prescott peninsula, which stretches right down the middle of the proposed reservoir from north to south) will have to be acquired in their entirety, (206), that whatever elevation of water in the reservoir may finally be selected, taken together with the fact that the land around any of the proposed flow lines rises very steeply and rapidly (202), means that an increase in the height of the dam and of the capacity of the reservoir will require only a small amount of extra land; (181) that he is not competent to say whether any change in the legislation authorizing this construction, in view of the disposition of the application to the War Department for permission to take waters of the Ware and Swift Rivers, is contemplated; (182) that he knows of no report to the General Court of Massachusetts of the change made necessary in the plan due to the action of the War Department; that he is not able to say whether any is contemplated or not; that as far as his personal knowledge is concerned, he knows of no such report.

MR. J. WALDO SMITH, Consulting Engineer upon the present Metropolitan District water supply project, testified (2170) that in the spring of 1920 he was asked by the Joint Board to act as consulting engineer in the preparation and presentation of that report; (2177-2178) that in his opinion one-half to two thirds of the expense of the entire dam contemplated in the Swift River Reservoir would be for construction below the surface of the ground, inasmuch as very deep excavation had to be made in order to get to bed rock, all of which expense must be undertaken regardless of the height to which the dam is built above the surface of the ground; (2172) that in his experience with dams, aqueducts, and reservoirs he has never known one to be built too large, and that in a great many instances they are not large enough; (2182) that from his experience the Swift River Reservoir site was the best that he had ever seen; (2171) that a great deal of attention was given to available sources of supply for the Metropolitan District in the report of the Joint Board in 1922; that that board went through the same process that Mr. Stearns did in the 1895 report; that Mr. Stearns was very thorough and very capable and he laid out that district with a broad outlook to the future, with a broad policy, and that policy has been consistently followed which he thinks is the reason the Metropoliatn District has been so successful and the reason it is better than any other District he knows of; that since 1926 he has been consulting engineer for the Metropolitan District Water Supply Commission; (2177) that the reservoir and tunnels recommended by the Joint Board were to be built very ample in size and if required at some later day they would also take care of additions to that supply; (2178) that the site of the dam and reservoir does not lend itself to piecemeal construction so that it really calls for doing the work all at the same time; (2179) that these structures were designed to take care of more water than was immediately necessary; (2180) that there is no reason why other people should not get their water from this great reservoir up there that will hold this great quantity of water; that sometime Hartford or one of those cities will put

a pipe line up to the Swift River and have some of that water; that everything is along that line these days (2181) that the taking of water from other tributaries of the Connecticut River was not contemplated but was taken into consideration; that the other waters that can be put into the Swift River reservoir would be the Millers, Deerfield, Quaboag, and Westfield; that those are the ones that must be the next step in the development of the Ware and Swift.

MAJOR EZRA B. WHITMAN, expert for Connecticut, testified (344-345) that from the evidence given by Dr. Winsor, he believed that the Massachusetts construction work which has been done to date has followed very closely the recommendation in House Document (1922) No. 1550, Exhibit C-1; that from his experience in water supply engineering he would say that construction work being carried on in the construction of the tunnel and to be carried on in the suggested construction of the reservoir of the Swift River is far beyond what is necessary for the development of the Ware and Swift Rivers, in accordance with the legislation of 1926 and 1927, excepting where that legislation states that the works may be made big enough to take in other streams in the future; (1170) that in his opinion a higher dam would be much more expensive than a lower one, because it would require the acquisition of more land and additional foundation construction; that he estimated the cost of a tunnel of one half the capacity of that now under construction would be seven-tenths of the cost of the larger tunnel; (351-358) that the logical and sensible way of making use of the construction which he regarded as excessive, would be to take in the future additional waters from nearby and adjacent rivers, such as the Millers, Quaboag, Westfield, and the Deerfield Rivers, and divert them into the reservoir; that from his examination of the record of the flow of the Ware River from 1913 to date, the largest daily flow recorded by any flood during that time was 1375 cubic feet per second; that under

the legislation 131 cubic feet per second must be let down the Ware River, and that the remaining 1244 cubic feet per second could be carried by either the Ware-Swift tunnel, or the Ware-Wachusett tunnel with a 10% margin of excess capacity; (347) that he has made computations to show what amount of storage would be required if the City of Boston were going to take all the water from the Swift and Ware and not let any of it down; that without knowing the exact area of the land that would be flooded it is necessary to make more or less assumptions as to the percentage of the total watershed that will be under water; that his computations show that if there is five percent of the area covered by the reservoir that you can get practically complete development or yield of one million gallons per day per square mile; that the complete development would be 1.05, that is, the entire runoff per square mile is 1.05 million gallons per day; that it would require, with five percent water surface and 95 percent land, a reservoir of 140 billion gallons capacity to practically completely develop the watershed, and the yield would be (348) 270 million gallons per day.

MR. NATHAN B. JACOBS testified that the tunnel under construction as Dr. Winsor described it as to size and capacity, is practically the same as was indicated in the 1922 report (Exhibit C-1); that he does not think there has been any departure; (250) that the black line on Exhibit C-1 in the Swift River area defining the maximum flowed area in the Swift valley as testified by Dr. Winsor is the 1922 recommendations; that what he was testifying to as to the general plan of Massachusetts is practically the same as the 1922 recommendations.

DR. JOHN H. GREGORY, an expert witness called by Connecticut, testified (1263) that he believed a total storage of only 140 billion gallons in the Swift River reservoir would be

necessary to develop adequately the total water supply yield on the Ware and Swift Rivers, above the points of proposed diversion; that he did not believe that a reservoir holding 400 billion gallons would be necessary; that in his opinion a considerably smaller one would serve to take all the water; that the most practical place from which to acquire more water for the Swift River Reservoir would be from the watersheds in the vicinity of that reservoir, because it would not be practical to take Eastern Massachusetts supplies and pump them over to the Swift River Reservoir.

Several Massachusetts witnesses on cross-examination were questioned as to what in their opinion would be the method adopted by Boston for obtaining a further supply when the Ware-Swift project had become inadequate.

DR. FRANK E. WINSOR testified that how long before 1970 this would become important would depend, (725) upon the sources which might then be available and the length of time required to investigate them and to develop them; (721) that he estimated the Ware River Supply to last with reasonable safety until 1934, assuming that the water can be taken in 1931; that he stated that the area of the watershed above the proposed temporary diversion dam on the Swift River is 127 square miles; (723) that discussing informally with the District Engineer of the War Department the informal suggestion was made that water might be taken in this temporary way whenever the flow at West Ware on the Swift River exceeded 100 cubic feet per second; that on that assumption, he is under the impression that an additional yield of something like 35 million gallons a day on the average could be obtained; that with this, storage in the Swift River Reservoir ought to begin about 1940 so that (724) storage would be available a year or two later, he figures that the capacity of all these sources would be reached approximately by 1970, that

is including the waters of the Ware and Swift; that he gave as an estimate that investigation would begin from ten to fifteen years before the date when the Ware-Swift supply actually became inadequate; that he testified that (176) while the towns outside the Metropolitan District come into the Commission, some of the water supplies which these towns have, have outlived their usefulness; that they are from polluted waters; and are inadequate and the probability is that they (177) would be abandoned when they came into the Metropolitan District; that when the Metropolitan District takes in the additional population, the District will not necessarily take over the water supplies now used by this population; that they may abandon that supply when they request to come into the District; (178) that he has no plans as to what will be done with this water supply that will be discontinued; that it doesn't come under his jurisdiction; that he hasn't made any study to enable him to advise as to its ultimate destination; that as a rule those supplies are nearing the end of their usefulness; that they are obtained from waters that are polluted by large population and the reason for their abandonment is generally because of their unsuitability; that as to what they are going to do with that water, there is no reason why that should be of any interest to him; that it is of interest to the municipalities themselves; that when they think it is unsuitable, then they may come in; (179) that he has nothing whatever to do with looking over any water supply in any community to see of what use it can be made and that he doesn't know anyone who has—if they do, he doesn't know who it may be; (725) that fixing from 10 ot 15 years before 1970 when an investigation for a new supply will begin, he took into consideration the abandonment of the Cochituate supply first, probably the abandoning of the Ashland supply later, or the Ashland Reservoir; that practically it does include the abandonment of the supplies of these towns that are now supplying themselves, that are within the ten mile radius; that though he hadn't thought of it in just those terms but that is what it would amount to.

(1221) Q. If that Metropolitan District had to supply these other areas, you have exhausted their supply at the same time? A. The presumption is that the supplies have become inadequate.

Q. If that is so, then the Metropolitan District is faced with either going to the Merrimac or to these supplies in the other portions of Eastern Massachusetts that have been described as a Fifteen Watershed Plan, or the Ware and Swift, isn't that true? A. They have certainly got to get additional water.

Q. And in one of these three sources? A. They have got to get additional water, that is true.

Q. That is the three sources that are available, of water, normally in Eastern Massachusetts? A. I would say that you combed Eastern Massachusetts to the limit.

Q. So you have three distinct—

MR. WARREN. There is the Charles River, isn't there, Dr. Winsor?

THE WITNESS. There is the Charles River.

Q. Well, then, do you consider that a source of supply? A. I do not.

Q. No, so that from your standpoint you really have three distinct sources of supply, haven't you? A. I wouldn't agree with that. I don't consider that they are the only possible sources.

Q. But that is the maximum, isn't it? A. Possibly.

MR. WARREN. No, the Charles.

Q. You might question these two, you might question some of these other sources, but that in general is a description of what there is possible of development, if they can be developed? A. Well, if that problem was put up to me (1222), I would have to give it very careful consideration and very long study. That is, whether I would want to consider getting water from wells, or Martha's Vineyard, or at the North End of Cape Cod.

Q. Or the North Pole? A. Or the North Pole.

Q. Now, Dr. Winsor, you say that you are within ten gallons less.

Mr. Warren. What?

Q. Ten million gallons per day less on your estimate for 1970? A. If the Cochituate and parts of the South Sudbury are not in use.

Q. So that when that point is reached you must go somewhere else for water? A. If the District continues to grow beyond the limit.

Q. And there are no sources in Eastern Massachusetts that you would go to? A. Well, that is a question that would have to be solved in 1940.

Mr. Warren. 1970?

The Witness. 1970, I should say, in 1970.

Q. It will have to be solved much quicker than that, will it not, if you are going to be short ten million gallons per day in 1970? A. Well, I don't think that you could delay the solution as long as that. I think the future supply ought to be available in 1970. You might have to decide ten years before.

Q. I think you said from 10 to 15 years earlier? A. Ten to fifteen years earlier, that is it, of course.

Q. Would you expect to put in the eastern waters into the Swift reservoir? A. From the eastern part of the State?

Q. Yes. A. Why, I would not expect to, as far as I see the problem offhand. I haven't faced that problem. I wouldn't think so.

Q. (1223) So that if you wanted, then an additional supply, and if the Swift reservoir is to be used, it necessarily largely must come from the western past of the State? A. Well, I would not say that the Swift reservoir—the Swift reservoir would continue to be used anyway, wherever the additional supply might come from. It might come from wells alongside of the Charles River. By that time we might be distilling ocean water.

Q. Have you wells alongside the Charles River? A. I have never— I was just—

Q. So that they are not going to go in, and isn't it true—

Mr. Warren. Dr. Winsor, do you mean to say there are no wells along the Charles River?

THE WITNESS. There are many wells along the Charles River, but we haven't got them. I mean the Metropolitan District hasn't.

MR. WARREN. You must be very careful in answering Mr. Averill's questions to, because I don't think he is always directing his questions to the Metropolitan District. He is talking about the eastern part of Massachusetts. Now the Charles River at the present time, as I understand the situation, has some wells which supply at least in part the town of Brookline and the City of Newton, don't they?

THE WITNESS. Yes, and in addition to that they supply Waltham and Dedham and possibly some others.

MR. WARREN. They don't take the water from the river?

THE WITNESS. No.

MR. WARREN. But they take it from wells?

THE WITNESS. From wells.

MR. WARREN. Driven in the valley of the river?

(1224) THE WITNESS. They have got a very considerable supply from those wells.

Q. (1236) (By Mr. Averill) I think, Dr. Winsor, just before the *Mayor* went on, either you or Mr. Warren were talking about some wells, a considerable well development along the Charles River. How extensive is that development? A. I really cannot tell you. I never have been connected with that. I know in Newton, where I live, we get well water from the Charles. I know that Brookline, Waltham, Needham and Dedham, and I presume other places, take water that travels along the Charles River.

Q. Are those towns included within any of the district which you outlined today, either in the 13 towns, the 10 towns or the 20 towns? A. They are all included in one or the other of them.

Q. Do you figure on using these supplies after the Metropolitan District takes it over? A. A part of this available water that I spoke of would undoubtedly come from those supplies.

(1237) Q. Isn't it true Dr. Winsor, that when you reach your capacity or your demand by 1970, or before that, your next supply must come either from tributaries of the Connecticut River or the Merrimac River or the area included within this Fifteen Watershed area? A. Speaking generally, without having given that matter mature consideration, I would say no. There would be other sources.

Q. What are they. A. Lake Winnipesaukee, Lake Sebago—

Q. Lake Winnipesaukee is where? A. It is in New Hampshire. It could not be taken now.

Q. That is a possible source? A. It has so been considered for the last 40 years.

Q. Where is Lake Sebago? A. That is in Maine.

Q. Have you any other sources in Massachusetts other than those I have mentioned? A. I do not suppose—

Mr. Warren. Did you mention the Charles?

Mr. Averill. I did not. He said that was not considered.

A. (Continuing) I do not suppose that large quantities of water could be obtained economically from other sources in Eastern Massachusetts, although I would say if you are willing to pick it up in a dozen or 15 or 20 places, a few bucketsfull at a time, the same as this Assabet project, it could be done. It would be poor engineering but it might be possible. Without investigation I could not say.

Q. So that it limits you to the Merrimac or the tributaries of the Connecticut River for the future supplies of the Metropolitan District? A. No.

(1238) Q. What are the others? A. I mentioned some others.

Q. You would have to go to New Hampshire, Maine or the Connecticut River tributaries? There are no other available sources? A. Yes; I think there are probably

other available sources. I think the Hazen report mentioned other available sources.

Q. In Eastern Massachusetts? A. They are in Eastern Massachusetts, but I think they are interstate waters.

Q. There are no purely Massachusetts supplies other than those I have mentioned? A. Other than those you have mentioned and I have mentioned, that may be so. I have mentioned the possibility of picking it up in a dozen or more of these little puddles that fill up after a rainfall.

(1240) Mr. Warren. On page 123 of House No. 900 I find this, in the Hazen report: "Supply for Merrimac River Communities. Ipswich River developed as proposed can be used for Lawrence, Lowell and other cities in the Merrimac River district. It is considered, however, that Salmon Brook and adjacent areas, mentioned above, will probably give a more economical and satisfactory service to those cities, and this matter is not followed further."

And the Commission itself, in its report on page 40, under the heading "Proposed Alternative Plan," said:

"We are in accord with views expressed in the report of the Joint Board,"—

that was House No. 1550 of 1922—

"With reference to the desirability of eliminating from consideration the possibility of developing new supplies from such sources as the Merrimac River, Charles River, Shawsheen River, or the other watersheds heretofore frequently suggested but which are located outside of the State."

Mr. Averill. What is the rest of that paragraph?

Mr. Warren. "There are, however, some available additions of substantial amounts which can be made to the present Metropolitan Water Supply from comparatively nearby sources which will render it possible to defer encroachment upon (1241) territory in the west-

ern portions of the State for a considerable period."

Q. Now, Mr. Winsor, you heard that excerpt from page 40 read? A. I did.

Q. Have any of those "available additions of substantial amounts" been developed since this report was made, in Eastern Massachusetts? A. No, not to my knowledge.

MR. X. H. GOODNOUGH, since 1895 Chief Engineer of the State Department of Health of Massachusetts (1566), after testifying that the Ware-Swift supply will probably last until 1970, indicated that it was impossible to state now where the Metropolitan District will get an additional supply at that distant date in the future. He called attention (1602-1603) to the possibiilty that power companies making developments in New Hampshire and Maine might cooperate with Boston in the building of great reservoirs which could be used not only for power, but for water supply purposes. He cited the case of Springfield, Massachusetts, as in instance of such a co-operative undertaking.

MR. WESTON FULLER, an expert witness, offered by Massachusetts, testified (2031) upon cross-examination that it would be a great mistake to force the Metropolitan District to take an inferior supply under the conditions which now exist; that it was not a foregone conclusion that all future water supplies of Boston must come from the western section of the State, although in his own opinion he believed that the supply for Eastern Massachusetts ought to some from sources similar to the Ware-Swift, and that he believed that these sources could be found in the western part of the State; that he also stated he believed that the tendency of water supply experts was to overestimate the rapidity with which additional supplies would be needed, and that in his opinion the Ware-Swift supply would go for a few years beyond 1970; that he gave it as

his opinion (2032) that, if Massachusetts did go to other tributaries of the Connecticut River and if the War Department required Massachusetts to let down more water than naturally goes into the Connecticut in dry seasons, that it would benefit conditions in the Connecticut River.

DR. FRANK E. WINSOR testified (87) that the first contract was let for shafts in the spring of 1927; that in the spring of 1928 the contract or two contracts were let for the tunnel, the tunnel being divided into two parts extending from the Wachusett Reservoir; (88) that bids were opened in the fall of 1927 and the contract was made in the early part of 1928; that it was made as soon as the War Department acted on the Ware River application; (715) that up to this time the delay which might have been occasioned because both projects had not been undertaken simultaneously and contracts let simultaneously for the whole project, has not cost any additional money; that up to date, the Commonwealth or the district has not been in any way inconvenienced on its water supply; that the construction of the tunnel westerly from Coldbrook will become an important matter very soon because of the fact that the increment which may be expected in water supply from the Ware, will not carry the District for a much longer period that it will take to complete the tunnel, so that the construction of that tunnel from his viewpoint, as an engineer should be underway very shortly.

STREAM FLOW

DR. FRANK E. WINSOR, an expert witness for Massachusetts, testified (107) that a chart entitled "Relation of Authorized Diversion to the Flow of the Connecticut River in the Dry Year 1923" (Exhibit D-2) shows on the left-hand side the diversion authorized by the Massachusetts legislation, and on the right-hand side that authorized by the War Department; that the chart is meant to show a weekly hydrograph of the flow of the Connecticut River; that each horizontal line shows the amount of water in cubic feet per second that would have flowed in the Connecticut River on an average for each week during that entire year; that the heavy black area at the top of each of these peaks shows the amount of water which would have been abstracted from the Connecticut River during each week of that year under Massachusetts legislation; that the graph is prepared for the flow of the Connecticut River at the Massachusetts-Connecticut state line; that the area that is section-lined represents what continues to flow in the Connecticut River, and the area in solid black represents what is taken out; (108) that in the months from July to October, inclusive, the top of the line, instead of being solid, is broken, indicating that in those weeks the Swift River was contributing water to the Connecticut River in excess of what its flow would have been had there been no reservoir; that the War Department has required Massachusetts to draw upon storage and bring the flow up above what it would be if this reservoir were not built; (109) that a similar chart shows the same thing for the wet year 1928 (Exhibit D-3); that in that year it would not have been necessary to draw upon storage because of the high flow of the river at Sunderland; that the extreme minimum flow in the wet year of 1928 is shown for the second week in October and was considerably more than 5,000 cubic feet per second; (112) that Exhibit D-4 entitled "Connecticut River Hydrograph Massachusetts-Connecticut State Line—Weekly Average Flows before Diversion and Amounts Which Could Have Been Diverted from (and added

to) the Swift and Ware Rivers under War Department Findings of March 1928 and May 1929" shows the flow of the Connecticut River at the Massachusetts-Connecticut state line; that the *black area at the top represents to scale the amount of water that would have been diverted for water supply of the Metropolitan District had the works contemplated in the legislation of 1926 and 1927 been completed, and provided that the requirements of the War Department were complied with; that where the line is full *black, it represents a positive diversion; that where there is a broken line, it represents an addition to the flow; that the graph is made up week by week beginning January, 1913; (117) that the total drainage area tributary to the Connecticut River above the point at which it crosses the Massachusetts-Connecticut state line is 9,722 square miles; (120) that during the period July, August, September, and the first part of October, 1913, the flow of the Connecticut River would have been continuously augmented by water released from storage; that during the second week in September, 1913, for example, there would have been added to the flow of the Connecticut River from storage in the Swift River Reservoir 48 Cubic feet per second during the entire week; (121) that those figures show nothing about the Ware River because during the period from June 15th to October 15th the Commission would not be permitted to take water from the Ware River; that regardless of whether the flow is above the 85 million gallons per day which, under Massachusetts legislation, fixes the point at which diversion may begin, under the War Department regulations no water could be taken during the period June 15th to October 15th; (122) that the chart shows the weekly diversion from 1913 through the first week of December, 1929, also the tides on the Connecticut River at Hartford on days when the low tide went below 3 feet on the Hartford gauge; that 2 feet on the Hartford gauge, is the elevation to which the navigable depths are usually referred; that, in other words, a 10-foot channel in

* the areas and lines appearing black on the tracing being testified to appear *white* on the blue print filed.

the Connecticut River is supposed to be 10 feet deep below 2 feet on the Hartford gauge; (124) that the tides are not shown on the chart on days when they did not go as low as three feet; (126-127) that zero on the Hartford gauge is about 0.69 feet below mean sea level; (129) that the total watershed of the Connecticut River at its mouth is 11,300 square miles; (130) that part of the watershed is in Canada; that the total watershed on the Connecticut River lying above the Massachusetts-Connecticut boundary is 9,915 square miles, including some area in Massachusetts which empties into the Connecticut River in Connecticut below the state line; that this explains the variation between 9,915, which lie above the state line and 9,722, shown on the chart, which are tributary above the state line; (131) that the drainage area of the Connecticut River watershed lying in Connecticut, by subtraction, is 1,385 square miles; that the total drainage area of the Ware River is 221 square miles and at the point of partial diversion, 98 square miles; that the total drainage area of the Swift River is 213 square miles and at the point of partial diversion, 186 square miles; (132) that the drainage area of the Swift River at Bondsville is 195 square miles; that the Massachusetts legislation prescribes that there shall be a guaranteed flow at Bondsville of 20 million gallons per day; (133) that in making up that flow, the drainage area between the dam and Bondsville contributes, so that it is not necessary, under Massachusetts legislation, to draw all of the 20 million gallons per day from storage in the reservoir but only so much thereof as is necessary to augment the flow from the 9 square miles between the dam and Bondsville to produce 20 million gallons per day at Bondsville; that the War Department requirements do not relate at all to Bondsville, but the flow stated to be released is measured at the dam; that the population of the metropolitan area about Boston is 1,900,000; that the population of Connecticut in 1928 was 1,667,000; (134) that the diversion proposed on the Ware River under the Massachusetts legislation is: Flood flow in excess of 85 million gallons per day between November 30th and June 1st of each

year, no water to be diverted between May 31st and December 1st in any year without approval of the Massachusetts State Department of Health; that under the War Department restrictions, the diversion permitted from the Ware River is: Flood waters in excess of 85 million gallons per day for the period from October 15th to June 15th of each year; (135) that on the Swift River, under the Massachusetts legislation, diversion is authorized of all waters except those required to maintain a flow at Bondsville of 20 million gallons per day; that on the Swift River the War Department authorized diversion of all waters except those required to maintain a flow at Bondsville of 20 million gallons a day, except that during the period from June 1 to November 30, both inclusive, 110 cubic feet per second shall be released from the impounded waters when the flow of the Connecticut River at Sunderland, Mass., a town about 20 miles north of the confluence of the Chicopee and Connecticut Rivers, is 4,650 cubic feet per second or less, and when said flow of the Connecticut River is more than 4,650 and less than 4,900 cubic feet per second, 70 cubic feet per second shall be released; (136) that the War Department determined that a discharge of 4,900 cubic feet per second at Sunderland corresponds to an average lower low tide gauge height of 2.1, and a discharge of 4,650 cubic feet per second at Sunderland to an average lower low tide gauge height of 2.0 feet at Hartford; that the Metropolitan District Water Supply Commission's plans are being made in compliance with the War Department's decision; that he is not intending to go beyond the requirements of the War Department; (137) that the mean annual discharge of the Connecticut River at the Massachusetts-Connecticut boundary is about 17,000 cubic feet per second and that of the Swift River at the proposed Reservoir, about 300 cubic feet per second; that the mean annual discharge of the Swift River is about 1.8 percent of the mean annual discharge of the Connecticut River at the Massachusetts-Connecticut state line; that there would be some very wet years when the only release from storage in the Swift River Reservoir would be that required by the Massachusetts legisla-

tion and that there would be other dry years when a very large release would be required by the War Department; (139) that the drainage area of the Ware River at the point of partial diversion is 0.87 percent of the total drainage area of the Connecticut River and 1.01 percent of the drainage area at the Massachusetts-Connecticut state line; (140) that the drainage area of the Swift River subject to diversion is 1.64 percent of the total drainage area of the Connecticut River and 1.92 percent of the drainage area at the Massachusetts-Connecticut state line; that the total watershed subject to partial diversion is 2.93 percent of the total watershed of the Connecticut River above the Massachusetts-Connecticut state line; (1418) that the flow of the Connecticut River actually diverted by the Ware and Swift project under War Department restrictions averages about 2 percent; (1416) that the average annual flow of the Connecticut River at the Massachusetts-Connecticut state line corresponding to 17,000 cubic feet per second is 542.1 billion cubic feet per year; that the average net annual diversion under Massachusetts legislation as modified by the War Department is 10.8 billion cubic feet per year, corresponding to about 300 cubic feet per second; (1418) that of this 10.8 billion cubic feet, which is the net total annual diversion, 8.1 billion cubic feet, or three-fourths of the total, is taken away when the Hartford gauge reads above elevation 7.4 or 17.4 feet above project channel bottom; that 2.1 billion cubic feet, or nearly one-fifth of the total, is taken away when low tide on the Hartford gauge stands between 3.5 and 7.4 feet; (1419) that in other words, a total of 10.2 out of 10.8 billion cubic feet, or 94 percent of the total diversion, is taken out when low tide on the Hartford gauge stands above elevation 3.5, or 13.5 feet above the project channel bottom leaving a balance of some six-tenths of a billion cubic feet of the total of 10.8 billion cubic feet, which is taken out when low water on the Hartford gauge is below 3.5 feet; that, however, if at any time low tide is below 2.1 on the Hartford gauge, which corresponds to 12.1 feet above the project channel bottom, the interests of navigation are safeguarded by the release

of stored waters from the Swift River Reservoir under the requirements of the War Department, so that the navigable depth is slightly increased at times of lowest flow; (1420) that the amount of stored water which would be released under the War Department requirements, and which will increase the flow in the Connecticut River above what it would have been without any development of the Ware-Swift diversion project, averages about 146 million cubic feet per year, or three one-hundredths percent of the average annual flow of the Connecticut River at the Massachusetts-Connecticut state line.

MR. NATHAN B. JACOBS, an expert witness for Connecticut, representing Morris Knowles, Incorporated, testified (251) that he had made a study of the stream flows of the Connecticut River and tributaries, having available for this study the same records of the United States Geological Survey in regard to stream flow that Dr. Winsor had; that records of the stream flow of the Ware River are available from August 20, 1912, of the Swift River from July 15, 1910, of the Connecticut River at Sunderland from March 31, 1904, and at Thompsonville from July 14, 1928; (252) that the hydrograph of the weekly flows of the Connecticut River (Exhibit D-4) is substantially correct; that so far as weekly flows are concerned his results are substantially the same and there is no quarrel as to the figures; that he had made a hydrograph of the Connecticut River at Hartford; (253) that there is very little difference between the two, except that Exhibit D-4 is on a weekly basis and his is on a daily flow basis; (254) that this chart (Exhibit C-5) shows the daily low water gauge heights at Hartford; that the influence of the tide reaches above Hartford up to a point where there is a dam known as the "Enfield Dam"; that when the gauge at Hartford indicates about 8 feet there is no noticeable tidal effect at Hartford owing to the great amount of water coming down the Connecticut River; but as the gauge goes down, the tidal effect is felt

at Hartford; (256) that on this chart the vertical scale is not a direct reading scale. (In the first block, that is from zero to two feet, each of the blocks represents two-tenths of a foot. The same is true in the block from two feet to four feet. In the block from four feet to nine feet each of the spaces represents five-tenths of a foot. In the block from nine feet to nineteen feet each block represents one foot. In the block from nineteen feet to thirty-nine feet each space represents two feet); that this was done so as to condense the record to a short interval of height on the chart, and at the same time to be able to show the difference in smaller amounts than a foot at times of low gauge; (258) that this graph (introduced in evidence over the objection and exception of Massachusetts) is not confined to showing the effects of the diversion only from the Swift and Ware Rivers as modified by the War Department findings, but indicates the maximum diversion in cubic feet per second from all of the Connecticut River tributaries which have been mentioned in reports upon water supply for the Metropolitan District, namely, the Swift, Ware, Millers, Quaboag, Westfield and Deerfield Rivers, assuming the same diversion from the Millers and the Quaboag as from the Ware as authorized by the Massachusetts legislation and from the Westfield and Deerfield as from the Swift as authorized by the Massachusetts legislation; that this diversion is indicated on the graph by the dotted line at river stages of 4 feet and less at Hartford; (259) that these diversions from six rivers would be four and three-fourth times the diversion from the Ware and Swift; (263) that Exhibit C-6 is a graph for the period from 1913 to 1926 showing the gauge at Hartford in feet on days when the gauge was 16 feet or more, and shows the reduction which would have occurred in that gauge on the basis of the diversions from the Swift and the Ware; that 16 feet was selected because that is the flood stage on the Connecticut River at Hartford; (267) that on March 30, 1920, the reduction in stage at Hartford would have been four-tenths of a foot or approximately 5 inches, and the river stage on that day was 22.5 feet at Hartford; (269) that the Government project for

navigation is a channel 10 feet deep below the zero of the Hartford gauge; that the project has never been carried out, the most that practically obtains is around 10.5 feet below mean low water, or 2 foot stage; (270) that there is a depth of about 10 feet of water in the river when the Hartford gauge is 2 feet; that there should be, to meet the Government project, 12 feet in the river when the gauge is 2 feet; that between Hartford and Springfield, there is no channel dredged, and when the gauge at Hartford is 2 feet, there is a depth of about 3 feet of water; (272) that on May 3, 1921, there occurred the day of maximum effect on the Hartford gauge considering those days when the Hartford gauge was more than 16 feet; that the effect on this days was a reduction of 0.55 feet, or about six and one-half inches; that on this particular day the diversion would have been the same either under the Massachusetts legislation or the restrictions of the War Department; (274) that flood water is generally defined "that which overflows the banks of a stream"; that sometimes they say that anything above the lowest annual maximum stage that has occurred over the record of the gauge is flood; (275) that the Ware River has never overflowed its banks at Gibbs Crossing, the site of the United States Geological Survey measuring station on that river, from 1913 to date; that looking at it purely from the standpoint of overflowing the banks at that particular point, there have not been any flood waters in the Ware River during this period; that the lowest high flow of any year on the Ware River was in 1918, March 24th, amounting to 547 cubic feet per second at Coldbrook; (276) that according to the rule of the lowest annual maximum stage, only the flow in excess of 547 cubic feet per second would be considered flood water; that with 547 cubic feet per second flowing in the Ware River, the line of demarcation between ordinary flow and flood flow had been reached; (277) that on that day, with 547 cubic feet per second flowing, there would have been diverted all in excess of 132 cubic feet per second, or 415 cubic feet per second, which is 76 percent of the total flow of the stream; (278) that the dictionary definition of

flood is "An unusually abundant flow of water in a stream rising and overflowing land not commonly covered with water; an inundation, freshet or deluge; flood stage, the lowest stage of a river at which overflow will begin"; (279) that in 100 square miles of drainage area, a flow of 85 million gallons per day would not be considered flood or flood waters except by special definition; (283) that Exhibit C-8 shows the daily diversions from the Ware River for 1927 under the Massachusetts legislation; that the correction for the War Department's restrictions on this river is purely one of time and would mean that if one were to consider it on the basis of the War Department's order, one would merely disregard those dates which occur between June 15th and October 15th, inclusive; (300) that Exhibit C-11 shows the daily flow of the Connecticut River at Thompsonville for the year 1923 and the diversions which would have taken place under the Massachusetts legislation from the Ware and Swift Rivers; (301) that Exhibit C-12 shows the same information for the year 1929; (304) that the solid black portion of the columns shows the ratio of the diversion to the flow of the Connecticut River; that the dotted lines show the same thing by weeks and would correspond in a general way with Exhibit D-4; (305) that in some weeks there is a wide distinction between the maximum and minimum flows and in some weeks there is not; that in the week covering the last part of October and the first part of November, 1923, the flow varied from 2,000 cubic feet per second to about 40,000 cubic feet per second; that the following week the rate of flow was from about 23,000 cubic feet per second down to as low as about 10,000 cubic feet per second; (306) that it is generally found that Monday is the day of lowest flow; (308) that Exhibit C-13 is a statement by years of the number of days from 1913 to 1927, inclusive, that the flow of the Ware River at Coldbrook would have been greater than 85 million gallons per day, the amount stated in the Massachusetts legislation; that, for example, in 1927 on 227 days out of 365, there would have been a flood in the Ware River under the Massachusetts definition of flood; (309) that

Exhibit C-14 shows the diversion under the Massachusetts legislation from the Swift River for each day during the calendar year 1927; (310) that during the year 1927 there would have been diversion from the Swift River every day but two, namely, October 2nd and 3rd; (312) that the year 1929 was a dry year, and that the year 1923 is the best example of a normal year on the Connecticut River; that 1923 was not as dry a year as 1929; that 1921 was drier than either of them; and that the very dry years were 1914 and 1915; that Exhibit C-15 shows the maximum flow of the Swift River on any day during the year for each of the years from 1913 to 1929, and the total amount of flow that would have been diverted under the Massachusetts legislation; (601) that Exhibit C-6-A shows the lowering in stage of the Connecticut River at Hartford at times when the water at Hartford stood at 16 feet or more on the gauge due to diversion as proposed from the Ware and Swift Rivers, subject to the so-called Army restrictions; that the only difference between Exhibit C-6 and Exhibit C-6-A is that the latter shows a slight reduction in the amount of diversion possible on two days, namely, July 10th and August 6th, 1915; that under the Massachusetts legislation there would have been diverted from the Ware and Swift Rivers 700 cubic feet per second on July 10, 1913, but under the Army restrictions it would have been possible to divert only 558 cubic feet per second; that August 6th, under the Massachusetts legislation it would have been possible to divert 2,134 cubic feet per second, which under the Army regulations, the amount of diversion would have been 1,610 cubic feet per second; (607) that Exhibit C-8-A shows the daily diversions from the Ware River for the year ending December 31, 1927 under the Massachusetts legislation and also under the restrictions of the Secretary of War: (609) that Exhibit C-14-A shows the daily diversions from the Swift River for the calendar year 1927 based on the Massachusetts legislation and also under the restrictions of the Secretary of War; (611) that for example, on October first of the flow of the Swift River was 112 cubic feet per second, and the Army restrictions require that

110 cubic feet per second be permitted (612) to flow and therefore there was retained in the reservoir 2 cubic feet per second of the natural flow of the stream; that under the Massachusetts legislation, there would have been diverted 76 cubic feet per second on that day; (613) that on October 2, 1927, the natural flow of the Swift River was 107 cubic feet per second and under the Massachusetts legislation, there would have been diverted 81 cubic feet per second out of this flow; which would have left 26 cubic feet per second to flow past the dam; that under the Army restrictions on this day, the natural flow of the stream would have been supplemented by 3 cubic feet per second; (614) that Exhibit C-14-B shows the daily diversions from both the Ware and Swift Rivers for 1927 both under the Massachusetts legislation and under the restrictions of the Secretary of War, and this statement is the total of the figures shown in Exhibits C-8-A and C-14-A, and is simply a matter of addition; (615) that Exhibits C-23-A, C-23-B and C-23-C show the diversion, the first from the Ware, the second from the Swift and the third from both combined, for each day during the year 1923, both under the Massachusetts legislation and under the restrictions of the Secretary of War; that 1923 would be termed a normal or an average year for the Connecticut River; (616) that during the history of the last 14 years, there were only 14 days, or an average of about one day a year, when the natural flow of the Swift River was less than 20 million gallons per day at Bondsville; that the legislation provided that when those days occurred, an average of about once a year, water should be let out of the reservoir so as to increase the flow at Bondsville, up to 20 million gallons per day; that because those days occur so very rarely, the 20 million gallons per day being practically the minimum daily flow of the stream, the Army Engineers' restrictions said that when the flow of the Connecticut River at Sunderland got down to 4900 cubic feet per second, instead of being satisfied with 20 million gallons per day at Bondsville, there will have to be released from storage enough to bring that flow up to 70 cubic feet per second, and when the flow of the Connecticut River gets

down to 4650 cubic feet per second, the release will be 110 cubic feet per second from storage; (617) that during August 1913 the natural flow of the Swift River would have been augmented under the requirements of the Secretary of War practically all the time; (617-618) that this increase in flow would go down the stream into the Connecticut; (619) that there were not many days during July, August, September and October of 1923 and none from about the 24th of August until about the 24th or 25th of October when the natural flow of the Swift River would not have been so augmented, (up to 110 cubic feet per second or up to 70 cubic feet per second depending upon the gauge at Sunderland); (622) that the year 1915 was a dry year on the Connecticut River, but there would not have been so much water let down in 1915 as in 1923, which was an average year; that during an average year there might have been let down considerable water because the flows of the Swift and the Ware were low, while in a dry year, 1915, when water was needed very badly in the Connecticut River, Massachusetts might have been letting down less than the natural flow of those streams; (623) that the average flow of the Connecticut River at Sunderland is 13,900 cubic feet per second, which corresponds with 17,000 cubic feet per second at the Massachusetts-Connecticut state line; that in 1923, the annual flow was 13,500 cubic feet per second, or within 400 cubic feet per second of the mathematical average; that while the average was 13,900, 1915 was 11,500 cubic feet per second and 1914 was 10,800 cubic feet per second; that the flow at Sunderland in 1927 was 15,300 cubic feet per second; that 1916, 1920, 1922, 1925 and 1928 were all slightly wetter years than 1927; (624) that the year 1920 had the highest annual flow of any year since 1914; (627) that Exhibit C-13-A shows the number of days per year when diversion from the Ware River would have been permitted under the restrictions of the Secretary of War; (628) that for the year 1913 water could have been diverted under the restrictions of the Secretary of War from the Ware River on 126 days, or the same number of days in that year as it would have been

possible to divert water under the Massachusetts legislation; that in 1919, the number of days on which diversion was possible was 196, which was the largest number of days in any one year; that in 1915, under the restrictions of the Secretary of War, water could have been diverted from the Ware River on 73 days, and 81 days under the Massachusetts legislation; that on the average, water could have been diverted from the Ware River 138 days per year under the Army restrictions, and 145 days per year under the Massachusetts (629) legislation; that Exhibit D-15-A shows the maximum daily flow for each year on the Swift River, and that the amount of diversion possible from this river under the Army regulations was 100 percent of the stream flow in every case; (629-630) that the reason that there was 100 percent diversion on each of these days was because the flow on eight square miles below the dam and above Bondsville was equal to 20 million gallons a day and because there was so much water going down the Connecticut River that the War Department restrictions did not apply to the Swift River on these days; (634) that Exhibits C-25-A and C-25-B represent estimates of the average effect of the diversion of water from the Ware and Swift Rivers on the Connecticut River at Hartford, that they are based entirely on averages and not upon flows on any specific day; that C-25-B is based upon the Massachusetts legislation and C-25-B upon the restrictions of the Secretary of War; that they show the effect both in cubic feet per second diverted and in feet reduction in stage on the Hartford gauge, and also the percentage of time over the 25 years' record that this effect would have been felt; (635) that, for example, when the stage at Hartford is three feet, equivalent to a flow in the Connecticut River of approximately 8500 cubic feet per second, or 0.806 cubic feet per second per square mile, assuming this rate of run-off prevailed over the entire drainage area, the diversion from the Swift River under the legislation would have been 125 cubic feet per second, and there would have been no diversion from the Ware, so that the total diversion would have been 125 cubic feet per second, which is equivalent to a lowering of the gauge at Hartford of

four one-hundredths of a foot or one-half inch; that this difference on a 3-foot stage at Hartford occurs about 15 percent of the time; (636) that the improvement under the Army Engineers' restrictions occurs at a gauge height of 2.1 or less; that the average addition would amount to one-eighth of an inch on the gauge 80 days in the year and one-quarter of an inch on 33 days; (637) that Exhibit C-25-A shows that if the diversion is carried out under the Massachusetts legislation, the Hartford gauge would on the average be lowered, during that 22 percent of the time when the Hartford gauge stands at 2 feet, by two one-hundredths of a foot, whereas, with the War Department restrictions in effect, the diversion would result in an increased gauge height at Hartford in the amount of one one-hundredth of a foot; (638) that on the average, with 5200 cubic feet per second flowing at Hartford, which would keep the gauge at just the minimum required by the Government project, this Massachusetts plan would have an effect of reducing the depth of the water one-quarter of an inch, and with the Army Engineers' restrictions in effect, it would result in increasing the depth at Hartford by one-eighth of an inch; (640) that when the gauge at Hartford is 12 feet and the flow correspondingly is 45,500 cubic feet per second, the reduction on the average would be 0.27 feet, or three inches; (646) that based on average figures, the lowering of water at Hartford, due to diversion under the restrictions of the Army Engineers would vary from adding two one-hundredths of a foot at the very low stages to reducing it by three inches, when the Hartford gauge is at 11 feet above zero; (656) that the average flow of the Connecticut River at the state line as testified to by Dr. Winsor, namely, 17,000 cubic feet per second, is correct and also, as testified by Dr. Winsor, that the average diversion under the War Department's restrictions is 2.01 per cent; (2224) that to the question:

> "Referring to the testimony of Dr. Winsor, page 1416, concerning distribution of the quantity of water diverted from the Ware-Swift River, with regard to the Hartford gauge, do you understand that whenever the Hartford

gauge gets to two feet or less navigation would be improved by the working of the project contemplated on the Swift River under the restrictions of the Army Engineers, as testified to by Dr. Winsor?" he replied: "No, I don't understand that at all, that that is correct. I have before me a statement showing the number of days when water will be released in excess of the normal or actual, I mean in excess of the actual flow of the Swift River under the Army Engineers restrictions, and this shows the number of days in each month from 1914 to 1927, showing an average of 37½ days a year. The second page of that statement shows the number of days that the Hartford gauge is two feet or less at lower low tide, and shows that that will occur on an average of 67 days a year. Or almost twice the number of days that water will actually be released. There is also attached to that, a statement showing the typical or the maximum diversions on specific days compared to specific gauge heights on the Hartford gauge. And this showed, therefore, that the improvement would be less than 60 percent of the time;"

(2225) [The statement referred to by Mr. Jacobs in his testimony on page 2224 was filed as Exhibit C-41. On page (2233) it was agreed that defendants should later supply an Exhibit similar to C-41 for the years 1913, 1928 and 1929 not included therein to be marked D-36.]

NAVIGATION

FRANK E. WINSOR, Chief Engineer, Metropolitan District Water Supply Commission, (68) testified that separate applications were made on the same date to the War Department for permission to divert the waters of the Ware and Swift Rivers; (69) that no plans other than those defined in the legislation were filed with the War Department; that no plan of the intake dam on the Ware River was filed other than the general plan defined in words by the legislation; (95) that the 131 cubic feet per second mentioned in the War Department communication is equivalent to 85,000,000 gallons per day; (104) that the gauge at Sunderland, Massachusetts, is approximately the same distance from Hartford as the proposed dam on the Swift River is from Hartford, figured as the water flows; (105) that the 31 cubic feet per second mentioned in the War Department communication is equivalent to 20,000,000 gallons per day; that the 70 cubic feet per second mentioned in the War Department communication includes the 31 cubic feet per second provided in the Massachusetts legislation—this 70 cubic feet per second is more than twice as much as Massachusetts requires; (696) that no formal request has been made and no permit or authorization has been issued by the War Department to erect the temporary dam proposed on the Swift River.

NATHAN B. JACOBS, representing Morris Knowles Incorporated, an expert witness for Connecticut (658) testified that periodic reports concerning the development of navigation on the Connecticut River between Holyoke, Massachusetts, and Long Island Sound have been made since 1867; that annual reports as to shipping, showing tonnage and value, have been made by the War Department; (665) that a navigation project for the Connecticut River between Hartford and Long Island Sound was adopted by Congress about 1880, providing for a 10 foot channel; that on February 27, 1911, Congress adopted

a project providing for a channel 300 feet wide by 15 feet deep across the bar at Saybrook, the mouth of the river, and 100 feet wide by 12 feet deep af mean low water between Hartford and Long Island Sound; (666) that the distance between Hartford and Saybrook, at the mouth of the river, is about 52 miles; that the reports of the War Department show that 11 feet has been the controlling depth between Hartford and Long Island Sound, which is one foot less than the authorized project depth; that there have been numerous reports recommending the establishment of a navigation project between Hartford and Holyoke, (667) but no project has as yet been adopted; that the reports of the War Department show that the navigation between these two points is primarily pleasure boats; that in the permit issued by the Federal Power Commission to the Northern Connecticut Power Company for a new dam at Windsor Locks the restrictions of the Chief of Engineers require the construction of adequate locks to accommodate navigation; that there are locks now existing and records are kept of the number of boats that pass through; that these locks are in the power canal between Windsor Locks and Thompsonville; (668) that in 1927 the annual report of the Chief of Engineers showed shipments on the Connecticut River below Hartford of 592,922 tons, comprised principally of coal and petroleum products having a value of $36,029,655; that the coal tonnage was 250,535 tons, the oil and petroleum products 284,766 tons, totalling about 535,000 tons out of a total of 592,000 tons; that these figures include the Saybrook tonnage at the mouth of the river which is a small percentage of the total tonnage; that the Hartford and New York Transportation Company and the Standard Transportation Company carried between 80 and 90 per cent of the total tonnage shipped on the river; (674) that the Hartford and New York Transportation Company ran both freight and passenger service from Hartford to New York; that in 1927 there were 7,681 passengers from New York to Hartford and 17,659 passengers from Hartford to New York; that in 1927 there were 288 trips by steamers on the river, having a draft of between 10 and 12 feet; that there were 4 by motor

vessels having the same draft, and 352 by barges; that there was also equipment on the river for a lower draft; that there were about 17 motor vessel and 170 barge trips by craft, having a draft of between 8 and 10 feet; that there were some trips for very low draft, 22 motor vessels and 1 barge; (675) that the net registered tonnage was 240, 322 for steamers, 3,761 for motor vessels, and 345,861 for barges; (676) that for the years ending June 30 from 1912 to 1926 inclusive the Federal Government spent $326,994 for new construction, and $323,700 for maintenance of the channel; that the records of the Standard Transportation Company show that in 1929 the depth at mean low water over 20 bars located in the channel between Saybrook and Hartford ranged from 9 to 10 feet; (677) that this is the actual depth recorded by the people who navigate the river, made from soundings by skippers on the boats and the barges; (678) that the annual reports of the Secretary of War and the Chief of Engineers always divide the Connecticut River into two parts: 1, the Connecticut River below Hartford, from Saybrook to Hartford; and the other, the Connecticut River above Hartford, from Hartford to Holyoke; that mean low water registers two feet on the Hartford gauge; (681) that the coal rate from New York to Hartford is $2.65 per gross ton by rail; that the rate by vessel is from 95 cents to a dollar; that the coal rate from New Haven to Hartford by barge is 75 cents per gross ton; (682) that the rate by rail is $1.20; that most of the coal is shipped from New York and New Jersey points to Hartford; that the bar depths given are to the nearest half foot, in other words 8 ft. may be 8½ ft. or 7½ ft.; (683) that the report of Major Pillsbury dated June 22, 1915, House Document No. 132, 65th Congress, 1st session, says that above Middletown it has been found impracticable as yet to maintain the channel to full width on account of the extensive shoaling brought about by the annual freshets.

JEREMIAH E. BECKWITH, of Saybrook, Connecticut, pilot and steamboat master (830) employed as a pilot for some-

thing like 40 years, principally in the Connecticut River and on Long Island Sound, testified that he was familiar with the channel of the Connecticut River and the bars located in the River; (831) that the bars are located substantially as shown on complainant's exhibit 28; (833) that he has been employed by the Standard Transportation Company for the past ten years; that he made something like 100 trips last year; that his Company put 204 barges through the Lyme Bridge last year; (834) that the approximate tonnage per barge was about 1500 tons; that they have experienced difficulty in navigating the river a great deal of the time on the low water; that on the low river the channel in places on these bars is any where from 60 feet to 100 feet wide, more of them at 60 than at 100, and there is no place on the bars in an ordinary low river where there is 10 feet of water at low water; that there is about 10 feet of water just over the bars at mean low water; that the bars varied anywhere from 500 feet to one half mile long in the channel; that the channel outside of the bars varies from 12 feet up to 15, but the 15 are very scarce; (835) that the bars in the channel have to be dredged every year in order to navigate the river at all; that the dredging commences sometime in the middle of June or the first of July and continues until sometime in November when they can get money enough to do it; that last year they dredged about two and a half or three months; (836) that last year there wasn't much effect from the dredging on these sand bars in the channel as they just took the lumps off; they just skimmed it off; they didn't have much to do with; just merely took out enough so it was possible to get over; that the natural depth of the Connecticut River if it was left alone would be somewhere around 7 or 8 feet on those bars; that this dredging is all done by the United States Government; (837) that his Company brings up the river oil, gasoline, kerosene oil, fuel oil, and naphtha, all products of the Standard Oil Company; that the load on each barge is about 9,000 barrels, and sometimes, in the freshet, ten or eleven thousand; (838) that they bring up a little more in a freshet ordinarily than they do on a low river; that the capacity of each barge is 15,000 barrels,

which is what she could be loaded to with 12½ foot draft; that because of the depth of the river they confine their load to 9,000 barrels instead of the capacity load of 15,000 barrels; that from his experience on the river he does not see where any amount of water, great or small, could be spared; he thinks we need more; that he has seen times when he has had barges ashore on the different bars; that the last inch which could be obtained on high water was the one that floated the barges; (839) that from his experience on the river an inch of water is important; very often the last inch is what gets them over the bar; that half an inch would do half as much good; (841) that when the gauge at Hartford shows between 3 and 4 feet, the presence or absence of half an inch of water in the river would make a difference in navigating it because the barges are only loaded to a 9 foot draft but could be loaded to another foot or two deeper and so bring up much more; that because of the absence of half an inch of water when the gauge at Hartford registers between 3 and 4 feet a low load must be carried on the barges; that the trip up is always on the tide; generally leaving Saybrook two and a half or three hours before high water in New London; that the trip up the river is made as far as possible on the flood tide and then the trip is resumed on the next tide; (842) that, if the flood tide is coming in the afternoon and the trip clear through to Hartford can be made, it makes twelve hours difference or so with us; that if the barges have to lie overnight at Middletown or Rocky Hill the whole night is lost and the barges have to wait until the next tide the next day; that sometimes, by not being able to get through, the barges on the trip up are caught in a fog, whereas, if the trip up could be made without interruption nearly twenty-four hours could be saved; that such delays are all due to low water in the river; that the best days are generally Tuesday, Wednesday, Thursday and Friday; that Saturday, Sunday and Monday are poor days; that this is on account of the mills at Enfield and along the river shutting down Saturday noon or Saturday night and stopping the water from coming into the river which makes about six inches to a foot difference on Sunday or Monday morning; that they

navigate every day in the week they possibly can, and a good deal of the time at night; (843) that the spread of the tide at Hartford is about 18 inches although the government figures it at 14 inches; (844) that the fall is the time of year when they have the most trouble getting over the bars; heavy westerly winds and northwest winds, Saturdays, Sundays and Mondays a great deal of the time, blow the water out of the river and makes it a good deal lower; (845) that the government usually begins dredging after the freshet recedes, after the water gets down to something below seven feet on the Hartford gauge; that that would be sometimes May and sometimes up to the middle of June; that the Hartford and New York Transportation Company has done the dredging for the government; (847) that after it is dredged it is improved a good deal; that the improvement continues generally until the next spring unless some boat gets ashore and kicks the sand up into a lump or something like that; (848) that the 1927 flood had about the same effect as an ordinary freshet would, although a high freshet like that causes more current and it forces more stuff down the river that accumulates on the bars.

THOMAS REED, Saybrook, Master and Pilot (849) employed by the Hartford and New York Transportation Company for about twenty years; testified that he handles towing craft, towboats; that the Transportation Company also runs a line of passenger boats between Hartford and New York; that the passenger line is now under the name of the New England Steamship Company; that he put 100,000 tons of coal into the Hartford Electric Light Company at South Meadows this last year; that it is brought up in barges; that his company brings coal to the Hartford Coal Co., the Mason Coal Co., and the Hatch and North; (851) that when you have 10 feet of water in the river, a half inch or an inch makes a big difference; that on his draft he has to work the tides to get the barges up; that on a low river the barges are loaded anywhere from 10½ to 11 feet draft; that over an inch of water is needed on some of

the bars to get over; sometimes if he gets ashore it is necessary to wait until the very highest flood tide—nearly the top of high water to get them over; that even a half an inch is a big help and an inch sometimes does the trick; that they leave Saybrook on a rising tide, on the first of the flood tide, and work that tide up as far as maybe Middletown or Rocky Hill; that if the tide begins to fall they have to anchor and wait for another one; that there is a delay sometimes of eight or ten hours, sometimes twelve hours, on a low river; that at freshet times it doesn't matter so much; that it would require seven or eight feet on the Hartford gauge to provide a sufficient volume of water in the channel of the river to go ahead with navigation without delay in putting a fair load on the barges; (852) that that would be with ten and a half or eleven feet in the channel; that the loading of barges is governed altogether by the conditions on the river; that in freshet time, when there is plenty of water in the river, they are loaded to their full capacity anywhere from eleven to twelve feet draft, averaging anywhere from 800 to 1,000 tons; that when the river falls off to ten feet over the bars the barges are lightened making a difference in tonnage of anywhere from 200 to 300 tons per barge; (853) with the Hartford gauge between three and four feet, if any water is taken out, it will have an effect on the draft; that anything loaded a little deeper will have to be lightened up a little; that the cargoes are all loaded by the stage of the water occurring in the river; that the more water there is in the river the deeper the barges will be loaded; that means more draft; that the lower the water the lighter the draft; that the towboat itself draws about nine and a half feet; if the barge is light, and with nothing, it draws about four feet; that the navigation in the river wears on the keel of the vessel; that the bottom of the Connecticut River is nothing but sand, mostly hard sand; especially on hulls it scrapes the sheets and wears them down and wears them to the plates; that he has sometimes seen it wear into the rivet heads or make them leak around the plates; that it wears along the shoe or keel; that they have a false shoe; (854) that the towboats are equipped with shoes for the purpose of stopping the wear on the hull; that

sometimes they have to be renewed; that where most wear occurs is right at the stern where they draw the most water; that the draft on the tugs is lessened to nine and a half feet in the river; that on Long Island Sound and the ocean the draft is anywhere from eleven to twelve feet; that most of the barges are from the coal ports, Amboy, South Amboy, and Jersey coal ports; (855) that the tugs are lightened at Saybrook by the letting out of water ballast; (856) that a reduction of the level of the water in the river of a quarter of an inch would be a little too fine for them to consider letting the water out of the ballast tanks; it would not be worth while figuring that out; (857) that an inch in the lowering of the water affects the navigation on a low river; that all the depth possible is needed but that a variation of an inch would not affect his company with respect to lightening its tug when starting up the river; that usually three to four barges are taken on a single tug when coming up the river, towed one behind the other; that the reports of the condition of the river come from the Hartford office; that a report is obtained at Saybrook of the condition of the river, if there is a rise in the river or the river is very low; that he does not remember getting a report from Hartford of a change of an inch or less in the reading of the gauge; (859) that if one of the barges was loaded to a twelve foot draft it would need about 12½ feet of water over the bar; that 6 inches clearance is the least allowance; (862) that if the water is too high it is necessary to dock, and generally we do not come above Middletown when the water is over the banks; that is, in an eighteen or twenty foot freshet, the tows do not generally come up to Hartford with night coming on; that the low levels of the water are from August to November; that sometimes late in the fall they have very low water conditions; that if any additional water was going to be supplied to the river, when it would be wanted would depend on whether any rain or anything to help the stage of the river occurred; usually it would be required between July and early November; that an inch of extra water at that time would be a big help; (863) that because of the condition of the river, it is not possible to carry the load which

otherwise would be carried; that it is found difficult to navigate the boats when the gauge at Hartford is from two to three or even four feet; shallow spots here and there are found with three or four feet on the board.

CHARLES R. BACON, Middletown, Conn., Master Mariner, (911) testified: That he was employed by the New England Steamship Co., that he carries passengers and freight between Hartford and New York, making three trips a week, going down one day and up the next; that his boat has some seventy odd state rooms and a number of berths, and is 1488 gross tons; that he has been employed in this work about 25 years; that the company has two boats making this trip; (912) that the trips are made daily; that the boat left Hartford every night; that an average of 100 tons of freight is carried each way each trip; that the New England Steamship Company was formerly the Hartford and New York Transportation Company; (913) that the low water in the river as it affects navigation comes along the latter part of the summer; (914) that the Hartford gauge shows ordinarily about 2 feet on an ordinary summer tide; that when the water is shut off over Sunday it is a common occurrence to see it go down close to zero; that he has seen it when it is aggravated by a northerly wind go off the board entirely; that when the Hartford gauge shows 2 feet there is an average of 10 feet on the bars; that a difference of one, two, three to six inches in water would make a big difference in navigation but perhaps a half inch is a little close; that, from the viewpoint of navigation, no water can be spared from the Connecticut River; (915) that the fact that none can be spared in the Connecticut River is founded on his experience as a practical mariner navigating the river practically every day; that, for instance, he went out of Hartford with 300 or 400 passengers aboard, proceeded about a mile or two, when his boat went aground; that was on Labor Day last summer; (916) that a fair schedule for their boats is made; (917) that if, on Labor Day, instead of water being subtracted

from the river, some water had been added, that would have helped; that it is the practice of power companies, manufacturers and mill owners up the river to hold the water back on Sunday; that that was one cause of the difficulty on the day he got stuck, (918) if some water had been added it might possibly have helped; that his boat draws ten feet on an average, but with freight the draft gets down to eleven feet; that, when the draft is that low it is necessary to wait for the tide to help out; that any delay depends on the stage of the tide and how fast the tide comes in; (919) that their trips are continued until about January 1st, although sometimes they run into February; the trips continue as long as possible; that the critical period, so far as the water is concerned, is along in September and October; that, with the gauge at 3 feet, perhaps the lowering of the water one inch would be a little too fine to consider, but two inches would be noticed; (920) that, if there was really a 12 foot channel over the bars, his boat would slide through very comfortably, but that is very seldom; that it does not stay but a very short time; that the banks come in, and as the boats go up and down that sucks up, and if unfortunately a barge goes ashore, in pulling her off the propeller wheels stir the bottom up, and it is no time before these bars are all torn to pieces; that if there is a ten foot channel, that is a good average—that is, ten feet when the gauge is at 2 feet; that if there is 11 feet on the bar a diminution of 2 inches would not make any difference, or at any higher stage; (921) that, as the stage went up, more water could be subtracted without interfering with navigation; that the channels in the bars are not wide enough so that boats can pass each other; that it was formerly understood that tow boats would give way to steamers, now they do not do so; that this is getting to be more trouble now than the low water; that the low water and the narrow channel and the other boats taking their part of it, creates a situation where sometimes two or three inches makes a big difference; (922) that a half an inch of water either added or subtracted is too small a difference to have any effect under these conditions; that very little water helps a lot, quite a good deal on the

trip up with the tide coming in; that it is surprising the small amount of water that will help when it is lifting and easing the current up.

WILLIAM H. HILL, Master Mariner (923) testified: That he was employed by the New England Steamship Company, navigating vessels and handling freight and passenger service between Hartford and New York; that he had experience on the Connecticut River for about four years; that navigation on the Connecticut River is increasing; (924) that the channel depth over the bars is not exceeding 10 feet with the gauge at Hartford reading 2 feet; that his boat draws on an average 10 feet; that loaded with passengers and freight it draws anywhere from 10 to 11 feet; that the period of low water is from September to November usually; that under normal conditions they always find it low every Sunday, weekends, Sunday and Monday night; that this is the period when the Holyoke Dam is closed and they are ponding water up the river; that any water released during that period to benefit navigation would have to be sufficient to fill that pondage; (925) that in his opinion no water can be spared out of the Connecticut River; there are times when there is not sufficient water now; that, with the gauge reading between 3 and 4 feet, in the light of his experience in navigating the River, no water could be safely taken out without injuring navigation; that there are times when on the trip up the tide has to be depended upon to help the vessels having a heavy load when the gauge at Hartford is between 3 and 4 feet; (925) that during the flood period the taking away of water would not work any damage or hardship to navigation; (926) that, from his observation when vessels have heavy loads, there is no more water than is needed when the gauge is between 3 and 4 feet at Hartford; that at sharp bends in periods of medium flood, difficulty is experienced in passing other crafts; (927) that, if any water were added during low stages, it would be welcome; that the most

difficulty is experienced with the bars usually after September to November, and sometimes there is a low period in the spring; there will be a period of a week or ten days sometimes when the bars fill up very quickly; and then if there happens to be a dry spell, much trouble is experienced in the fall until the bars are dredged, but usually before that the floods come; they don't intend to dredge until after the flood period because they cannot operate their dredge, and the strong current brings silt and sand and fills the cut up faster than a normal flow would at low stage; that the flood contributes to the height of the bars; that if there were no floods but a larger uniform flow, the navigation of the river would be easier, if there was enough water; that the dredging noticeably improves conditions; (928) that the amount of tonnage is increasing because there are other companies, although the amount of towing by the Hartford line has decreased.

HERMAN BURGI, Springfield, Massachusetts, Engineer and Master of Steamboats operating on the Connecticut River, (928) testified: That he has an unlimited master and pilot's license on the Connecticut River and Long Island Sound; that he is familiar with the Connecticut River between Holyoke (929) and the Sound; that between Hartford and Holyoke the River is very low in the summer, so that they are unable to go up and down with the boats as they would like; that they can get back and forth between Hartford and Holyoke in the spring and during the fall floods; that he has one boat that draws 5½ feet and one that draws 3 feet; barges are loaded to whatever they think they can carry; that he actually navigates between Springfield and Long Island Sound sometimes; that he is superintendent of the Springfield Navigation Company; that he has a 65 foot boat that draws 5½ feet, which he used to go up and down the river; that he has traveled from Springfield to Florida in it; that to navigate this boat he has to have 44½ feet on the gauge at Springfield; (930) that 2 feet on the

gauge at Hartford is equal to about 42 feet on the Springfield gauge, so that 44½ feet at Springfield would mean a 4½ foot gauge at Hartford; that, during the period when the gauge is at 4½ feet at Hartford, any diversion of water would affect navigation; that between Springfield and Hartford they are affected by small amounts of water diverted on account of 3 distinct sets of pools and 3 sets of rapids; one at Podunk, one at Farmington; one at Bissell's Ferry at Scantic; that those are the bars they have to overcome, and if the flow of the river isn't there the water runs out; that there is 8 feet 6 inches of fall between Hartford and the foot of the locks at Windsor Locks; (931) that he is acquainted with the river between Hartford and Long Island Sound, and agrees with the navigation situation as testified to by the other witnesses; (932) that while his 65 foot boat is a yacht and not a commercial boat, it is used sometimes as a tow boat for business purposes; that he has towed some boats of the Merritt-Chapman Wrecking Company from Hartford to Springfield; that he has taken other people who have done work up that way and had to be towed up; that he has to go thru the Locks at Windsor Locks to get up to Springfield; (933) that he has taken up pile drivers, dredging boats and so forth from Hartford to Springfield; that 3 years ago he took up 3 boats for the Scott Wrecking Company of New London, who were working on the north end bridge; that before that he took 8 or 10 of them up for H. P. Converse and Company, who built the new county bridge; that he agrees with the statement in the Chief of Engineers report for August 3, 1929 that no commerce was reported for last year, the only navigation being one derrick and 46 pleasure boats which passed through the locks of the Northern Conn. Power Co. at Windsor Locks, Conn.; (934) in 1912 the government did some work in removing and rebuilding the breakwater at the Farmington River between Hartford and Springfield; that he is engineer of the Springfield Gas Light Company; that his company sometimes does dredging at Springfield; (935) that from his observation of the river he would say that any addition to the water during the critical periods of low stages would be of benefit

if there is enough of it; that every additional cubic foot per second at low stages of the River would be some help; that, so far as navigation is concerned, if you could have an additional cubic foot per second in the low periods he would be willing to give up some of the flood waters in the high periods; (936) that he wouldn't want to give up any water during the period when you want 44½ feet on the Springfield gauge or 4½ feet on the Hartford gauge; that the River has got to have that to flow between Springfield and Hartford; (937) that it takes 2 more feet for us to get thru the rapids between the Locks and Hartford; that the 2 feet is an addition to mean low water at the Sound or 2 feet on the Hartford gauge; (938) that there is an application now pending with the War Department for a development of navigation between Hartford and Springfield; that they have had hearings on it; that the project is to give a lock 310 feet (939) long, 45 feet wide, with 12 feet depth over the mitre sill, that is where the gates come together; that there is a prospective development at Springfield for further transportation, to lessen the freight rate on coal; that the Springfield Gas Light Company uses roughly 100,000 tons a year; that they think they can lower the freight rate from 70c to a dollar a ton; that the city of Springfield was willing to build the terminal facilities demanded and they would also dredge from the channel to the terminal facilities; and that the other cities had offered the same thing; (940) that he expects the project to go ahead.

ROBERT J. NOBLE, of Brooklyn, New York (944) testified: That he is Vice President and General Manager of the Hartford and New York Transportation Company; that he is familiar with the Connecticut River between Hartford and Long Island Sound; that he has been on the River until this past year since 1882; that he is a sailor, fireman, barge-captain, deck hand on steam boats, general useful man from the office taking charge of dredging and so on, until he was made assistant superintendent; that his company dredged the river from

time to time for the government; that, when the government would not help, the company dredged it at their own expense; that the company dredged it for the government nearly every year; that he had charge of the work for 3 or 4 years; that during the freshet period no trouble in navigating other than the danger of bitting bridges or something of that kind was experienced; that when the low water season comes the steamboat company has quite some difficulty in getting its boats up and down, particularly until (945) the bars are dredged off; that unfortunately, several of the bars are in about the same condition at the same time, and having only one dredge only one bar at a time can be taken care of; that sometimes, not having finished a bar, the government allows the dredge to shift, to take the top off and shift to another bar, then returning and finishing the bars up, a rather expensive proceeding but it has to be done; that he has heard that the river has been dredged to 12 feet in depth but he was never able to find 12 feet of water at low tide; that he has not found exceeding 10½ feet; that last year his Company transported in coal, anthracite and bituminus, 223,550 tons, about 5,000 tons of fertilizer was handled; (946) that up to April 15, 1929, the freight and passenger service from New York to Hartford was handled by the Hartford and New York Transportation Company, but since that time it has been handled by the New England Steamship Company; (947) that the diversion of any water at any time that the Hartford gauge is below 5 feet would affect the Connecticut River; that additions up to 10, 12 or 15 feet would help navigation; (948) that the best and most economical period of navigation on the River is when there is from 6 to 7 feet of water on the gauge; that his Company would be glad to dispense with a great deal of water between March, April and May and would prefer an addition to the water increasingly as the river was lower in its stages (949) that the high water damages the Company steamboat landings; that dredging operations commence when the water is about 6 feet on the Hartford gauge; that the water drops very fast, and before one bar is nearly completed there is some other (950) bar that is bothering, and because some of

the Company Steamers may have gone ashore they ask for the privilege of going on that other bar, taking the crest of the bar off; but the crest can build up during the freshet season; that they were supposed to dredge so that the channel will be 12 feet deep at low water, but that depth is never found a few days after the dredging has been completed that the dredging went as deep as the government would allow; (951) that the government specifies where the material shall be dumped that is taken off the bars; that it is dumped in the river; (952) that in the bids the contractor is not obliged at any time to tow it over two miles; that with the exception of the bars there is plenty of water in the river; that the dumping of the material in the river has been done for a great many years; that with the little amount that is appropriated for the work in the Connecticut River, if it had to be towed over the Saybrook Bar, there wouldn't be money enough to dredge one bar; that the material is dumped in certain places, eddies and big holes that the government selects; that other bars in other places build up, that whether it is of that sand that is dumped in there he doesn't know but in several places that sand must go somewhere during the year because next year the hole is there to fill all over again; that he has noticed, since he has been on the river, the filling up of several new bars; that the bars fill up gradually; that it is probably two or three seasons before a new bar is first noticed; (954) that the channel has been changed due to the sand bars which have been added to, and the floods have brought some stuff down and deposited it on the bars; that the boats have real trouble when the Hartford gauge shows 4 feet, because with 4 feet in a heavy westerly wind there is rather low water at the lower end of the river where reliance is put on the tide to help a great deal; that with 4 feet of water on the Hartford gauge, the barges are rarely loaded to capacity since trouble is feared because with 4 feet of water on the gauge it is difficult to know what the conditions will be the next day or two hours later and because the barges are loaded at the coal ports; that the tendency is (955) for the water to fall, and if there is 4 feet the transportation company does not have so

much trouble from its barges the way it loads them; that if there were four feet on the Hartford gauge and the water was lowered ½ an inch a captain would be frightened a little bit, because he would not know where it was going to go; that no one knows that it is limited to ½ an inch; that nobody knows just what it will do; that when the river gets to lowering it lowers pretty fast in the dry summer time; (957) that the time lost because of delays in navigating the river is all reflected in transportation rates; that if, on any particular days of the year, when the water is low there is a half inch or an inch or two inches taken out of the stream, it affects navigation; that the actual navigation down the river is affected by a very small amount of water either one way or the other; (1004) that in 1929 the New England Steamship Company and the Hartford and New York Transportation Company combined; that the steamers carried 47,641 tons; that they didn't operate from February 4 to April 15; that there were also several days in the month of August when the steamer was disabled by shallow water; it hit a rock; that only one steamer was operating at that time; that the number of passengers handled was 36,671.

POWER

MR NATHAN B. JACOBS, an expert witness for Connecticut representing Morris Knowles, Incorporated, testified (318) than there is but one power site available on the Connecticut river within the State of Connecticut; (319) that at the present time there is a power development at Windsor Locks, with a dam situated at Enfield or Thompsonville; that Thompsonville is about 2 miles below the state line; (320) that the present dam is a low structure across the river, with a long canal, head-race, several miles long, carrying water which is used for power in certain manufacturing plants along the river; that the site for the development of power is about 3 miles below the dam; (321) that at present the power plant is able to maintain about a twenty-four foot head and to develop about 4000 horse power; that the present project is capable of further development in two ways, one by installing more generators or water wheels at the present site of the water power plant now used, and the other is to improve the development, obtain more head by building a dam farther down the river, but to the same height as the present dam; that thereby no more land above the present dam would be flooded than now, but it would develop a reservoir of larger area, the additional area being between the present dam and the proposed dam so as to avoid the long distance that the water is carried through (322) the present canal to the present power plant; that this new dam site would be at King's Island; that a reasonable maximum development of that (323) site would be about fifty thousand horse power; that figuring on the basis of a 50,000 H.P. development, the average loss caused by a diversion of the waters of the Ware and Swift Rivers according to Massachusetts legislation would be about 1,850,000 kilowatt hours per year; that the loss based upon the same facts except that the diversion be made according to the War Department's restrictions, would be about 1,320,000 k.w.h. per year; (324) that 1,850,000 k.w.h. per year is equivalent to 2,500,000 horsepower hours per year and 1,320,000 k.w.h. per year is equivalent to 1,770,000 horse-

power hours; (325) that the installation for a 50,000 horsepower plant will be the same whether there is a diversion or not; that the same physical equipment, same number and size of generators, same number and size of turbines would be installed; that they would be operated so many less hours because the water would not be there to operate them; that the productive results from the plant would be decreased 1% in case of a diversion under the Massachusetts Legislation and ¾ of 1% under the War Department's restrictions; that the total output of the plant is figured at 171,000,000 kilowatt hours per year; that such figure is net, based on the effect of the diversion, because at some times the diversion actually increases the amount of power that may be developed (326) at the plant, and taking the increases and subtracting them from the decreases, it gives the figure stated; that taking into consideration all benefits and losses which might accrue from these diversions, there will be a decrease of about 1% in productive results under the Massachusetts Legislation and ¾ of 1% under the War Department's restrictions; that a Federal Permit for a development at King's Island similar to the one described has been issued; that the project was authorized January 18, 1928, accepted by the licensee on January 25, 1928, and the permit issued on February 1st, 1928 by the Federal Power Commission (328) to the Northern Connecticut Power Company after having satisfied itself that the company had complied with the laws of the State of Connecticut and Commonwealth of Massachusetts and of its ability to carry out the proposed plans.

MR. EZRA B. WHITMAN, an expert witness for Connecticut, testified that (359) the methods employed by Morris Knowles, Incorporated, in figuring the effect of the diversions upon the power site at King's Island were correct and that the computations made are substantially correct; that the loss of power per year, based upon Massachusetts Legislation, would be 1,847,000 kilowatt hours per year (360) and under the

War Department's restrictions, considering what would be added, 1,320,000 kilowatt hours per year; that the same plant would be built whether diversions take place or not but practically the result of the diversion would be a reduction of 1% in the amount of power that could be generated (361) under the Massachusetts Legislation; and ¾ of 1% under the War Department's restrictions; (374) that a reasonable estimate of the value of the lost energy is 6 mills per kilowatt hour; (375) that the value of the current lost under the Massachusetts Legislation would be $10,800 per year; and under the War Department's restrictions, $7,920 per year.

MR. WESTON E. FULLER, an expert witness for Massachusetts testified (2021) that the loss in kilowatt hours testified by Mr. Whitman was substantially correct; that as far as damage to the power he did not agree; (2022) that water power development operated in connection with a public utility during the dry weather season is operated to the best advantage to take care of the peak loads during the day; in other words, there are certain hours during the day, perhaps four hours, when the load is very heavy; now, if there is a pondage provided so that the water can be drawn at a high rate for a short period, then this water power can be drawn upon, so as to relieve the entire system during these four hours; that that means that the steam plant, which is a necessary part of any development of this size to take up the load during the dry weather period, can be made smaller in size to the extent of that relief of the peak load, because that is the time when the maximum demand comes on the (2023) entire system; that therefore the release of water from the Swift River during the dry weather period is worth a good deal to the power company at Thompsonville; that during the dry weather there is probably about 80 cubic feet per second which is let down the river in excess of what would come down under normal conditions; that is, the total let down is 110 cubic feet per second and the dry

weather flow of the river goes, at times as low as 20 cubic feet per second, and he took it at 30 cubic feet per second, which leaves 80 cubic feet per second as the increase in dry weather flow; that if that water is all used during a period of four hours it means that it can be used at the rate of six times that, or 480 cubic feet per second during the time of the peak load; that that is capable of producing something in excess of 1000 horsepower; so that there would be a saving in the steam plant of this company of 1000 horsepower of steam installation (2024) which, taken at a minimum of $80. per horsepower, (it will probably run something more than that)—would be $80,000 which it would save due to the fact that it could save on its steam equipment; that the loss of power is at a time of the year when it is what is called surplus power; that there is no loss during the period of low water flow, and he thought that six mills per kilowatt hour, as Mr. Whitman suggested, is too high, entirely too high a value for that class of power; that that class of power is sold nearer three mills and sometimes at considerably less; so that in his judgment with the War Department's requirement the power at Thompsonville is benefitted rather than damaged due to the construction of these works of the Swift River under these requirements.

MR. WILLIAM F. UHL, an expert witness for Massachusetts testified (1809) that he did not know very much in detail as to the Windsor Locks proposition; that he knew that there is such (1809A) a place and that he had visited it and had examined reports on it that other engineers had made; that supposing it was a 45,000 horsepower development (1810) and it was proposed to divert 2% on the average, of the average flow of the Connecticut River, in such a way that about 80% would be diverted at the period of larger flow of the river and no water would be diverted when the flow of the river was in its lower stages, that he did not think the diversion would materially affect the value of the development.

AGRICULTURE

MR. WILLIAM H. CARRIER, of Glastonbury, Conn., a witness for Connecticut testified (744) that his occupation is that of farming; that he has a farm which starts about a quarter of a mile from the Connecticut River and runs east about three or four miles; that none of his land borders on the river but quite a bunch of it is in what is called the Glastonbury meadows; that he was born in Glastonbury and lives on the farm his father had; (745) that the Glastonbury meadows border on Glastonbury Main street and end at what they call the Naubuck or Glastonbury dock on the north; that these meadows are flooded every year to some extent, some years higher than others; that part of the farm is in these meadows and part is not; that in the meadows the best paying crop is hay; that the effect of these periodic floods is that land which is flooded the most is where the heaviest crops of hay are obtained; that they have never had to use any fertilizer on this hay land; that they depend entirely upon the flood waters for fertilizer; (746) that the land that is flooded the deepest is where they get the heaviest crop of hay; that some freshets don't cover the high land, where there are high knolls, and that the crop is always light, a good deal lighter than the ones that are covered; that in his opinion as a farmer, the second generation on the same farm the floods in the Connecticut River are of benefit to the farmers owning property along the river where they cut hay; (747) that they keep all of their hay for use in their dairy business and feed it all on the place; that they cut all there is; that they always do so; that some of the lowest part is in pasture; that the biggest part of the hay on the meadows in his neighborhood is cut except in a few swales where water is on it; there may be a little bedding left but the best part of the meadow is cut; (748) that all they pretend to raise on their meadow land that is flooded is just grass and pasture; (749) the reason is that they have land for other purposes and depend on the meadows for hay; that they can get the hay without expense and the rest of the land they have to fertilize; (750) that if

you had to raise hay on the upland it would cost money to raise; that you would have to stock it every three or four years, put on plenty of fertilizer; that most of it is not fit for hay anyway; it is lighter land; it is land suited to raise corn; that the 1927 fall freshet made one-third to a half more hay on the meadows; that in the last few years he has made no money on the land upon which hay or other crops are grown; (751) that it did not reach any of his other land; that they have less trouble with a good high freshet than a half way one; that with the higher ones there is not so much clearing up to do; it all floats away; the 1927 freshet was an extremely high one; (752) that on an ordinary flood, a reduction of three inches in height couldn't be figured in dollars and cents; it would mean three inches less; there would be just a little more land not covered or what was covered would be three inches less in depth; that one inch probably would not make much difference one way or the other, but inches make feet; that three or four inches on a freshet like 1927 wouldn't make an awful lot of difference; that on an ordinary spring freshet it all counts, that he does not know how much difference three or four inches would make; that every inch counts, he doesn't care how high the flood; (753) that as to three or four inches on an ordinary flood, it would make that much difference, whatever that difference is; it makes so much more depth of water and the more depth of water the more benefit; that the less depth so much less is obtained of it; (754) that there is in the neighborhood of 600 to 700 acres in the Glastonbury meadows; that is the area normally covered by the floods; that the hay grown on the meadows is a good hay for dairy purposes; that it is timothy, a natural meadow grass that grows on that particular land and has for years; that some of those acres have never known the plow, just natural meadows; that high land around this section does not raise a hay that is profitable to feed to (755) dairy cows because it costs more to raise; that he starts growing tobacco and vegetables beyond the flood line and that where the flood normally covers, only hay is grown; that the raising of hay is what the meadows are adapted to; (757) that during

wartime he plowed up a few acres of meadow and tried to raise corn but it was not a success; that is the only crop he had tried to raise except hay; that the meadow land is in the tax list for something like $150 an acre; (758) that land where he raises tobacco is in for about five or six times as much.

MR. EDWARD A. ISAACSON of Wethersfield, Conn., a witness for Connecticut, testified (758) that he is a farmer and contractor; that the land on which he raises tobacco is in the tax list for about five or six times as much money as the land that is flooded; (759) that he has between six and seven hundred acres in his farm at Wethersfield; that he keeps cattle and horses; that he has no dairy cows at the present time but is preparing to have some, that last year he raised one hundred acres of corn on the flooded land or land that was flooded in the 1927 freshet; that he raises hay on the flooded land; that the yearly freshets are the making of the land; that he wouldn't give a cent for the land or care to own it if the freshet didn't go over it because he couldn't get manure enough to (760) raise crops and get good hay; that he probably does more turning over and seeding on this meadow land, this flooded land than the average farmer does; that he plows it up and seeds it down to herdsgrass; that he plowed up one piece that hadn't been plowed in about twenty years; that it showed considerable herdsgrass after being laid down for twenty years; that the freshet had kept it well manured; that he always had a crop on it; that he feeds timothy hay and alfalfa, clover mixed in; that he has fifty acres of alfalfa down there now; that it looks fine; that he hadn't tried alfalfa until last year but it looks good this spring after the snow and ice are off; that he never has to use any fertilizer whatever and he gets wonderful big crops; that he gets fully three tons of hay per acre to the first cutting and a total of over three hundred tons on a hundred acres; that the second crop of herdsgrass grows, crisscrosses, on account of it being so rich; that it is all tangled up and when cut and brought to market it is

so rich you can't make them believe it isn't a first crop; that the advantage of the flood water to the meadow land caused him to buy a farm on high land adjoining it where he can keep stock and stuff without being very far away, and if the flood water wasn't on it he wouldn't have made those preparations; (761) that the more flood water the better the grass obtained; that it is sandy bottom and naturally drains out quickly and the floods, even high water where it doesn't cover the top, seems to irrigate the lower parts of it and the lower parts are the richest; that he had tomatoes and things down there, and they grow fast; that sometimes the last three inches of a flood will cover twenty-five acres but if it didn't come down, the flood would never touch it at all; that he thinks that the lower you get to the river without getting where you get too soft, the richer the land is and the bigger the corn grows; that he had that experience last year close to the river; (762) that he never thought that evergreen corn that would grow twelve feet on the upper land would grow sixteen feet high down close to the river; that his land is covered now, the part next to the river; that as soon as the river flood raises a foot there are a few acres more flooded and there might be forty acres with another foot; that when it raises fifteen feet it might cover twenty-five acres more; (763) that the 1927 flood covered approximately 400 acres of his land; that it still shows great improvement from what it did before; that the highest part of it seemed to get a great silt improvement on top of it and it still does it good; that the 1927 flood did not leave debris and refuse but carried it away; that some freshets leave some refuse, hay and grass and stuff that rakes have not taken clean, which they generally light a match to and burn up; (763) that the flood of 1927 went so high that everything floated on top of the water and it carried a lot of debris and stuff that was left there from lower freshets that didn't go high enough to carry it all out; (764) that he has one place thickly wooded and some refuse and debris gets in between those trees and lodges and there are places where the silt goes over it and has raised the land a foot a year, making new land; that he has a lot of acreage that has

grown from filling up; that he doesn't have to clean up his land after ordinary freshets; (765) that considerable damage was done by the 1927 freshet all the way from Vermont to Saybrook; that every city had considerable loss; that some buildings, cellars, etc. were filled with flood waters; that farmers along the banks of the river lost poultry and parts of their farms during that flood; that his barn (766) in the city, the cellar was full of flood waters; that it seemed to bother cities most; that he thinks that was a detriment; that at very high stage it would have benefited to take some away; that six inches of that flood would have made no material difference to him; that on a normal spring flood three inches one way or the other makes a big difference sometimes because if the water comes up three inches and a great big field were on one level, those three inches would just cover it with enough of this water that has this sewage and one thing or another in it, that it makes it grow twice as much crop; that it wouldn't be just three inches of land, but that three inches might cover a level of 50 to 100 acres; that with his particular farm land six inches of water in the high floods wouldn't make any difference excepting that the more area it would cover in the average spring freshet the better; (767) that he doesn't know what it is; that it is dirty water; it washes in from the river in all directions and it purifies on its way and it still takes in more that has not been purified; his land is five to six miles below Hartford; doesn't know as it can be the sewage from Hartford but it is something in that freshet that keeps the land very fertile, and it makes land; some of his land is at least five or six feet higher than when he bought it because of the silt left by freshets; that it keeps rising every year, in some places near the sand beach it will fill in four and five feet in one year; that where the river used to be, he is now plowing and raising corn; that it used to be a very low spot in there when he bought it and it has grown and raised up and now is one of the highest spots he has; (768) that he heard that celery was covered by polluted water and that that was the reason why they didn't know whether they would let it be sold or not; (769) that the flood

this spring, not a very high one, covered about 300 to 350 acres; that a July flood of 24 or 25 feet when he was a boy ruined the crops, ruined them to a certain extent, got the hay more or less dusty, etc. (772) that his land runs from 24 or 25 feet above low water mark to the waters edge; (773) that some hay in his barn was wet by the 1927 flood; that he used the part not wet.

MR. STANCLIFF HALE, of Glastonbury, a witness for Connecticut testified (774) that he is a farmer occupying a farm in Glastonbury which has been in his family since 1701; that part of the farm lies along Glastonbury meadows; that he has twenty-two acres of good hay land and forty-six acres of pasture land and a considerable amount of meadow land; that he considers flood water as it comes down in natural state of value to his property; that in years when freshets didn't cover all land, he had applied a little fertilizer to some of his higher areas particularly to bring out and help the second crop, but where floods cover he has never fertilized; that if part of flood water was taken, decreasing the area flooded it would be advisable to fertilize lightly; that one (775) might get the full benefit of one's land and crop; that he gets his entire hay crop from the meadow; that he has a better crop of hay than some of his neighbors who are dependent entirely on fertilizer on the upland; that he gets hay from the meadows that is good to feed dairy cows, neat cattle and horses; that his land goes down to the river at a very gradual slope and on the lower end of this piece, it was originally an island, that has been filled up; that there was a growth of willow on the south side, on the river (776) side, and every year that is filling up with silt and the willows catching more or less of flood debris and it is filling, in times of normal freshet at the rate of possibly four inches a year; that normal freshet he considers from 18 to 20 feet there; (777) that on 22 acres of hay land normally covered, three quarters of it has excellent hay; that this year he cut this

but allowed a neighbor to have the balance which was not so good; that the market for hay is considerably less than it was 25 years ago; that one end of this piece slopes very gradually from the river; that there is a line (778) of an old river bank and from there on is what is called "made land"; that they use six acres of flooded land for pasture and are seriously contemplating changing the type of farming to where that can be used and that, he would say, is a dominating factor in several of the men's minds who own considerable acreage, how they can adjust and start in some other crops there; that there is a piece of alfalfa, some corn and some potatoes that are grown on this meadow land; that he has only grown hay on his land; that the year following the 1927 flood, he had more than an average crop of hay; that he thinks it helped the hay; that there is not much difference in his town under present conditions of agriculture from the standpoint of profit in raising hay in Connecticut or raising vegetables or tobacco; that in either case farmers lose money; (779) that on one part of his land the flood cast considerable debris and refuse; that this was on pasture land; that he hauled nearly forty loads of wood off; that they were light loads, probably half to three quarters of a cord and consisted of railroad ties, bridge timbers and everything else; that they kept them warm all winter; that he knows of innumerable buildings being flooded; that there are land developments, land sold in the meadows which are flooded about every year; (780) that this is a detriment to such places and probably a danger to health; that those were unhealthy places to live in flood times unquestionably, and that they would be more healthy if the flood didn't come; that people will continue renting and think cheap rent overcomes danger of whatever they may get; that as a residential district the premises as a whole would be better if not flooded but not so as to agricultural district; that he considers it a reflection on a person's intelligence to build and live in such a place; (781) that he was speaking of developments on both sides of the causeway in East Hartford; that the highest point of his meadow land requires a freshet that is registered at Hartford of 20 feet to cover it; that as to how

much effect three inches would have or how much would be uncovered if flood was 19 feet 9 inches freshet instead of 20 feet freshet he couldn't go (782) into details of inches but the higher that land is covered over and the longer there is a flow of silt over it, the more it will settle and improve that land; that he considers that a 20 ft. flood will cover every foot of meadow land in Glastonbury; that if 20 foot is the exact measurement a reduction of three inches would cut down his best quality hay land six to seven acres or from a third to a quarter of the total; (784) that from 17 to 23 feet is the ordinary freshet; that the flood water improves tobacco land the same as it would any other land; that the silt has a fertilizing value, how much he doesn't know but the addition of humus which comes from erosion of other land up the river has always a value to it; (785) that the silt deposited by the normal freshet is of assistance to such tobacco land as it covers; that he doesn't raise tobacco; that he doesn't want to see another flood like that of 1927.

MR. LEWIS W. HOWE of Glastonbury, a witness for Connecticut, testified (786) that at present he is president of the Glastonbury bank; that he has lived in Glastonbury for fifty-nine years; that he owns a farm; that he owns land that is periodically flooded by the Connecticut River on the Glastonbury race land and the log landing meadow; that he raises hay on this land; that twenty years ago he raised tobacco in the log landing meadow; that during the war he had 10 or 12 acres of corn down there; that he is sure that these periodical inundations are a great benefit to this land; (787) that he has never had to fertilize the land for hay but did when raising tobacco; that every year he gets a better crop of hay when there is a spring freshet; but most always there is a good crop of hay in the Glastonbury meadows; that in the event that this flood water was taking away more or less, the part of the land that was inundated or covered with the flood would suffer because of

that taking away; as the river would cover it if permitted to flow in natural course; (788) that in 40 years there hasn't been much difference in one year from another as to floods except in 1927; that he thinks that from 25 to 28 feet is the normal flood freshet; that he has over 25 acres of hay land that he cuts hay on that is inundated with a 21 or 22 foot flood; (789) that three years ago he stopped cutting hay and has sold it standing ever since; before that he cut and used considerable of it for horses; that it has all been cut except there may have been a little of the low land, two or three acres last summer that wasn't cut; that there hasn't been as much demand for hay in his section in the last three or four years but they are commencing to keep cows now and there is some demand; the demand for hay is really poor but is getting better in his section now; last year he got about $10. per acre for the standing grass which is about half what he got two or three years before; that the land would probably average better than two tons to the acre; (790) that the 1927 flood left no refuse and debris on his land; that he has no meadow land; that a 20 foot flood will not take the debris right off; that only a subnormal flood will leave debris on his land; that he hasn't raised tobacco for nearly ten years; that the silt helps any crop that is grown on the land,—corn, potatoes, grass or tobacco.

MR. ALFRED W. HANMER, of Wethersfield, a witness for Connecticut, testified (792) that he is a grocer and first selectman of Wethersfield; that the town owns some land along the river that is periodically covered by freshets; that the town grows hay on this land; that there are about 20 acres flooded, about 10 acres they cut grass on and about 10 acres is used for pasturage; that that part upon which hay is grown has not been fertilized since he can remember; that is about 50 years; that every inch of the hay is cut; that it is a good quality of stock hay; that the town always cut it and fed it out to horses kept for street work until the last two years; (793) that they

sold it standing last year for $15. per acre; that is was a good crop of grass; that the keeping of dairy cows is increasing throughout this section of Connecticut; that milk is being graded and under strict supervision of the State Health Department; that milk sold in Connecticut must come from an inspected herd; that farmers have gone into raising and keeping milch cows and selling under these regulations; (794) that this land has never been fertilized; that about 900 to a 1000 acres of land in Wethersfield are flooded by the normal spring flood; (795) that he knew of several acres of celery condemned after the 1927 flood but that only happened once in seventy-five years; that they sold their hay standing the past two years because the state tested their herd of cows and took them all away and didn't think it advisable to invest in more cows; that they didn't want to spend the time and money and didn't have the force to cut it; that they would probably have realized more per acre for the grass had they cut it and put it into the barn but they had so much highway work they couldn't do it, that they couldn't afford to do it.

MR. RAYMOND A. HARDIN, of Glastonbury, a witness for Connecticut, testified (796) that he is town clerk of Glastonbury and has been an assessor of the town for 21 years; that he has lived in the town forty-eight years, that he owns about 38 acres of meadow land; that it has been in the family a great many years; that there are about 900 to 1000 acres of meadow land flooded in the town of Glastonbury; (797) that this total consists of three meadows, Keaney Point meadow in the north section, the meadow from the Glastonbury dock down to what they call Red Hill, and the south Glastonbury or Nagog meadow; that he sold all the hay on his meadow standing because he has two or three farms and he has sold hay and raised tobacco; (798) that they do not raise very much tobacco in the Glastonbury meadows except there are 50 or 75 acres in the Nagog meadows; (799) that he has never found

it necessary to fertilize any of his land that lies in such proximity to the river that it gets the benefit of these periodical floods or freshets; that if the flood water was taken away they wouldn't get any hay; (800) that he had not tried anything but hay on his meadow land; that he has noticed that if there is a high freshet, when the water comes up 25 to 27 feet they have better hay than they do when it is 25 or 20 feet; that the higher the freshet the better hay they get as a general thing; that in 1928 they had a good crop; that a rainy season gives a better crop than a dry season; (801) that last year for some hay he got $12.00 and some $10.00 per acre standing; (802) that during the war years he got a good crop of hay, and that it was about the average crop; (803) that good meadow is assessed for $125.00 per acre; bedding is in for $20.00 to $25.00; that tobacco lands in Glastonbury are assessed from $200.00 to $500.00; that he cut a second crop of hay on his land; that it is generally true that a second crop is cut on their land; (804) when sold standing some sell the first crop and cut the second themselves but he sells both crops.

MR. WILLIAM R. DUNHAM, of East Hartford, a witness for Connecticut, testified (810) that he has lived in East Hartford about 45 years; that he owns in the neighborhood of 35 acres on the bank of the Connecticut River which is periodically covered by freshets or floods; that it is assessed on an average of $125.00 per acre; (811) that he cuts the hay from this land; that he has never found it necessary to fertilize the land; that when he gets suitable floods he cuts a good crop of hay and without floods he does not get much; that he gets from two to three tons per acre; that he gets two crops; that the second crop is good hay for stock or milking cows; (812) that without flood water the land would be worth very little; that it would hurt that portion of his land which would not receive the benefit of the flood water if any part of it were taken away; that up to two or three years ago he use to sell

hay standing; that he received from $15.00 to $20.00 an acre for it; that the last two years he got two tons on the first crop and from one ton to 1000 lbs. the second crop; (813) that was the usual yield; that he has noticed a variation in some years; that the crop has had a difference of from 1000 lbs. to a ton some years; thinks that the crop last year 1929 was short but good quality; that the year before 1928 it was extra good; that was the year following the big freshet and they had considerable rain; (815) that they generally got a good crop from the land; that he grows a finer quality of hay than timothy; that it is a wild hay but a good hay; that it is a good deal like red-top and some of it grows white clover on the bottom; last year there was a lot of it with white clover on the bottom; that they have been over it for purposes of cultivation, but nothing excessive; that they stick it down a little and it will grow an immense crop of timothy for two or three years; that he has tried a little corn on it two or three times; (822) that during the war, he raised only hay on the flooded land.

MR. GEORGE A. HOLLISTER, of East Hartford, a witness for Connecticut, testified (805) that he is a councilman of the town of East Hartford; that he has lived there all his life; that he owns about 40 acres in the meadows on the Connecticut rim which is periodically flooded; that he gets from two to three tons of hay per acre from his meadows that have never been fertilized for a hay crop; (806) that he doesn't cut the hay, he sells the standing grass; that if the land did not receive the flood water periodically, it wouldn't cut very heavy hay; that the land always cuts two crops; (807) that the crop varies from year to year and depends somewhat on the flood conditions, and of course in a wet season the hay will grow better than it will in a dry season; that he didn't get as big a price for hay the last two or three years but that prior to those last two or three years, he got about the same price every year; (809) that there are breakwaters

along the edge of the meadow to keep the river from cutting the bank, prevent erosion; they are not high enough to keep water from meadows.

CHARLES E. GOODRICH, Glastonbury, Conn., a witness for Connecticut, testified (816) that he is county commissioner of the county of Hartford and lives in Glastonbury; that he owns land along the Connecticut River that is periodically flooded; that he owns approximately 30 acres; that he grows hay on this land; that the land has been in the family since 1700 and something; (817) that he had never known this meadow land to be fertilized; that he considers that the flood waters furnish the fertilization for the crops; that he gets a good crop of hay if he has high water; that he owns the highest knoll in the Glastonbury meadow; on that knoll you can always see the line of the flood water; that it takes a very high flood to cover the top of the knoll; and when one goes down to cut that hay one can often see the distinct water line on that knoll, the line where the freshet stops; that the difference in the height of the flood is indicated in the kind of crop that one gets there; that on the top of this knoll the land is just as good as the rest of it but the hay crop is light unless the water covers the knoll; that it takes a rise of 22 to 23 feet to cover it; that the taking away of the whole or any part of the flood water would work a damage to the land; that the damage in the illustration given as to the knoll, would be measured by the amount of flood that was taken; (818) that the higher the flood the more water there is over the land and the more fertilizer seems to get onto it; that if you have a good high flood you will get a fair hay crop even though it is a dry summer; if you don't get much of a flood in the spring you can have a lot of rain and you may get a fair hay crop; that the rain makes some difference but the flood makes a decided difference whether you get a good crop or whether you don't; that there is approximately 20 acres of his land which he considers good hay land; that the

rest of it is swale and goes to grass; there is only about an acre on top of the knoll; that he rarely ever gets flood water on the top of that knoll; that it take a very high freshet; that the grass is always very light on that knoll whereas the rest has good hay on it; (819) that the top of the knoll is noticeably higher than the rest of it; that it might be 8 feet; that they cut about 6 or 7 acres of hay themselves and the rest is sold standing; that up to 1925 he cut practically all of it; that he stopped cutting because he is not doing much farming now; that up until 1922 he used to keep a lot of horses, did quite a trucking business, and used to use all the hay himself for feed; that since 1925 he has only cut a small portion of it; (820) that for 2 or 3 years he used to cut the hay, put it in the barn and sell it out of the barn; that they always get 2 crops of hay; that the second crop, the rowen crop, grows heavy; sometimes it is not as heavy; that it is a good rowen crop; that he always had plenty of hay for his horses from his meadows; that there was a pretty even supply on the whole from the meadow; during the war he had a bunch of teams that were working for some of the factories and that sort of thing; (821) that they were feeding the hay; that they had hay enough; that since 1925, when he has sold most of the hay, the price has varied; he has sold it anywhere from $22.00 to $10.00 an acre; that last year he got about $12.00 an acre; that he thinks it averaged a little better in 1928; an average he would say of $12.00 to $13.00 an acre is the price for 1927, 1928 and 1929; that since 1925, the average price has been $12.00 or $13.00 per acre; that prior to 1925 the price averaged between $10.00 and $22.00 per acre.

WILLIAM W. ADAMS, Wethersfield, Conn., a witness for Connecticut testified (823) that he is a resident of Wethersfield and has lived there all his life, since 1870; (824) that he owns land along the Connecticut River and that practically all of it is covered by the freshets or floods; that he owns about 25 acres above what is called the causeway; that it

would take an 18 to 24 or 25 foot flood to cover it all; that it slopes toward the west from the River; that he has 25 acres more; some of it will be covered by the water where it backs up from Rocky Hill before it will come over the bank; that he gets no water in the Wethersfield Meadow; where it is pushed up there it will take a 16 foot rise to come over the meadow; that he considers the flood water a benefit to his land; that he has never been required to fertilize his land for a hay crop; that he cuts a good hay crop on the land; that he cuts it himself; that he sells some but feeds it mostly; that he cuts 2½ tons to the acre; that some will cut more than that; that it is good hay and he feeds it to his own stock; that if a part of the flood water was taken away it would damage his land to a certain extent; (825) that to get anywhere near the crop you get today would need fertilizer if the flood waters were taken away; that he keeps 25 head of stock; that he sold meadow hay last year for $26 a ton; that he put it in (826) the barn and held it; that most of the buyers are not buying hay until they get to the bottom of their own mow, but he has half a dozen calls now; that the crops on the land do not always run evenly; that you can tell the difference; that some years you will have better; that there isn't any question that the higher the water you get the better the crop; that he has never had to buy any hay; that if you don't get water over the banks you don't get the silt; that where it backs up you don't get the silt; (827) that the floods run from 18 to 23 or 24 feet in height; that if you go much above 25 feet you think you are getting a pretty good freshet; that from 17 to 24 feet you can get a pretty good crop and the meadows are pretty well covered; that that is pretty generally true in Wethersfield; that he has had some of the meadow land ploughed for corn and has had potatoes on some of it; that he had the corn on it in 1918; (828) that he got a good crop in that year; that it was yellow Indian corn; that he put 6½ acres into corn; that the corn was on the higher part of the meadow land; (829) that he fertilized it a little; that they always do, no matter where it is, to get it started quick; that the meadow land is apt to be a trifle cold; that if anything gets started

on the meadow land there is no place in the world where stuff will grow like on that meadow land after it gets root.

ANDREW CHRISTIANSEN, of Windsor, Connecticut, a witness for Massachusetts testified (867) that he lives in Windsor; that most of the Hartford farmers live in Windsor; that he is a market gardner; that Windsor is on the west side of the river about 3 miles above Hartford; that because of the flood in November 1927 he lost quite a little stuff, celery and carrots; that he had 600 bushels of carrots down in the meadow and the water got all that—3 or 4 feet; when the water went off the carrots were ruined; that he had a half an acre or an acre of celery and that was ruined; all of the rest he had out and up in cold storage so he didn't lose much; (868) that he has 3 greenhouses in connection with his business; that they are about 1000 feet from the bank of the river; that between the greenhouses and the river it is partly level but close up to the greenhouses it is low; when the flood comes up he will have about 10 feet in the hollow before it gets high enough to go over and run into the greenhouses; that in the flood of 1927 the water went up into the barn; that he had about 4 feet of water in the cellar of the barn; that it went into one of the greenhouses somewhat; that the reason he lost the celery and carrots was because the water stood over them too long before it went off, and when the water receded they had spoiled; that he figures his damage probably $2000, because he lost quite a lot of fertilizer, nitrate of soda, because he didn't get it up (869) high enough; he was used to the flood though he never used to get a flood like that, so he didn't get it high enough or he wouldn't have lost anything if he had known it; (871) that if water flows over his land, not as much as in 1927, but if some flood water flows over his celery land and his carrot land it does it good, because it leaves a lot of sediment or grease over the land and fertilizes it; that there was an awful lot of sediment left, and naturally he didn't have to put any fertilizer on it at all and

had a better crop; that when you have water going over your celery and carrots as in 1927 it ruins them, but they never expect to get a flood water in 100 years at that time of the year; (872) that it was a most extraordinary flood; that water going over celery and carrots to some extent would not hurt it, if it doesn't stand on it; that being so late in the fall in 1927, the flood water getting over it and the water settling down on top of it, spoiled it; that the present market for hay in his town is anywhere from $10 to $15 an acre; that there isn't very much demand for it; that he cuts all that he has; that he uses it for his own use; that there isn't quite as much of a demand for hay as there was a few years ago; that he thinks the floods help his hay land.

HAROLD M. NEWBERRY of South Windsor, Connecticut, a witness for Connecticut testified (873) that he has lived in South Windsor for 43 years; that he was born there; that he owns real estate touching the Connecticut River; that the Connecticut River is the west boundary of his property; that his family have owned the land for a great number of years; that there are approximately 15 acres of land on the river; that he grew hay on it to 1914; (874) that since 1914 he has grown hay on 3 acres and tobacco on 12 acres; that he doesn't fertilize the hay land but does fertilize the tobacco land; that the land on which he grows tobacco is subject to periodic inundation, possibly on an average of once in five years; that so far as tobacco is concerned he does not find that the freshets or floods in any way interfere with the fertility of the soil; that he has been able to get good crops on it; that he grows broadleaf tobacco; that he marketed part of his last crop to advantage; that it has been the best return of any land that he has per acre; that he grows tobacco on other parts of his farm on land which is not subject to yearly freshets; that he uses the same quantity of fertilizer on both lands; that any flood of approximately 20 to 24 feet will go over the land; that includes the land on which he grows tobacco; that since

1914 or 1915 the land has increased in height so that it doesn't flood as quickly as it used to; that it is gathering in height from the deposits of the floods; (876) that he thinks our floods are of shorter duration; that the flood is up and away quicker that it used to be but otherwise he doesn't see any difference; that the part of his land on which hay is grown is the first part flooded.

(888) It was agreed between counsel that in lieu of calling other witnesses concerning the effect of flood waters upon agricultural lands in the Connecticut Valley a stipulation should be entered into and made a part of the record; that the stipulation as follows was agreed to to avoid calling any more of the farmer witnesses:

STIPULATION

The plaintiff in the above entitled cause having offered several witnesses, who, being sworn, testified substantially that they owned acreage in the Connecticut Valley, so-called, which acreage was periodically inundated and covered with the flood water or freshets that in the natural course of events flow down the Connecticut Valley, and

The attorneys for the plaintiff having stated in open court that they offered witnesses to prove the acreage that was particularly covered by the freshets or floods in the Connecticut Valley and that all of said acreage was held and used as meadow land for the growing of hay to be used in feeding dairy stock, and that said hay was of an excellent quality and that they cut two crops of good hay each year,

IT IS HEREBY AGREED AND STIPULATED between the attorneys representing the State of Connecticut and the attorneys representing the Commonwealth of Massachusetts that the approximate acreage subjected to such freshets or floods or periodical inundations, is about ninety-five hun-

dred (9,500) acres, and that said acreage grows about two to three tons of hay per annum, which, when cured, is fed to cows and horses owned by the farmers or, in the spring following the harvest, can be marketed at approximately twenty-six dollars ($26.00) per ton, and that said hay while standing can be sold standing at a price ranging from approximately fifteen dollars ($15.00) an acre, to ten dollars ($10.00) an acre.

AND IT IS AGREED that the average price per acre would be twelve dollars and fifty cents ($12.50).

AND IT IS FURTHER AGREED AND STIPULATED that the witnesses summonsed, if called upon, will testify to substantially the above facts,

IT IS FURTHER STIPULATED AND AGREED that the annual inundations or freshets are of such character that the hay above referred to and described can be grown without fertilizer and that the flood waters are a benefit to this extent—that without the flood waters they could not grow as large crops of hay without fertilization, that diminution in the amount of flood water would be a detriment to such of the land as would not, because of such diminution, receive any of the flood waters and that the average flood varied from about seventeen to twenty-five feet above the low level of the river. Practically no crops other than hay are grown on any of the land which is regularly and periodically inundated or flooded.

DR. MONT FRANCIS MORGAN, an expert witness for Connecticut, testified (891) that he was a soil expert at the Connecticut Agricultural Experiment Station; that he had made a survey to determine the acreage in the Connecticut Valley which receives the benefits of flood waters or periodic inundations; that he had made a careful survey of the entire area which is in any way affected by (892) the floods, both soils and crops; that as a result of that survey and study, the total area

which is periodically inundated at some time or another is 13,000 acres; that these 13,000 acres include some other area besides the 9500 acres of hay land mentioned in the stipulation; that the 9500 acres are devoted exclusively to hay crops; that there are other crops; that his figures show about 750 acres of tobacco, about 480 acres of corn, about 250 acres of vegetable crops, 142 acres pasture, and 28 acres of potatoes; that those crops are not shown in the stipulation; that from his study and information on the subject and knowledge of the situation, he agrees with the farmers that they do not require fertilization on the meadow lands on which they cut hay; these meadow lands have received the benefit of flood waters which come down; (893) that there are usually certain lower lying areas, as a rule lying at the foot of the higher lands, which are never flooded; and these lower lying areas are inclined to be somewhat swampy; that then there is generally a slope, as a rule, rising toward the river, although this is not always the case; that it is not the case in some of the meadows in Rocky Hill and Wethersfield; (894) that as a rule the high point of the meadow land is at the river bed, but it is not always the same; that there are generally swells or occasional low depressions at various points over the surface of the meadow; that when the flood water rises it doesn't follow it with a uniform blanket all over the meadows, but there will be re-entrances and pockets where the flood waters reach and in some other places where they do not reach; that the conditions are such that these floods do not cover the entire flood plane—what we call the normal flood is a rather difficult thing to say; but consider what happens on the average year, such as last year was, the entire plane was not covered with water from bank to bank, when one considers the higher areas as the banks; that it comes up for a certain distance over that plane, leaving other portions untouched and the actual area flooded is for that reason varying from year to year; that only the higher floods, which occur every four or five or six years, cover the entire flooded area; that three inches diminution in the stage of the river would make a difference in the area touched or in the area

covered, particularly during periods of normal flood, because the flooded portion of the flood plane lies (895) over the area which is most affected by the average flood; that the higher floods rise up on steeper and more abrupt land, so a reduction in stage in those extremely high floods would make a relatively insignificant difference there on the extremely high flood, because by that time you are rising up to land where there is more slope; but on the average year, three or four inches would undoubtedly make a noticeable difference; that, as a matter of fact, it would leave spots here and there through the meadow land that are not touched at all by the floods, which would come within an inch or two of covering it; that there would be a reduction in the volume of water coming down the river by taking an inch to six inches from the flood water; that, with the improvement which is brought about by the sediments; there would be some difference in the acreage where they received a benefit on account of sediments and in other places none at all; (896) and that would tend to make a less uniform condition than usual; that it would be hard to say absolutely as to any given difference in flood change; that the fact that the plane is not of uniform slope or uniformly level, would tend towards a patchy or pockety condition; that any difference in stage of the flood of the area flooded would reduce the amount of sediment carried onto the land by the water; that if an inch were taken away from the flood, it might be necessary for the farmers to fertilize at the points where there would be no water in order to make a uniform hay crop, but that he doubts very much if the farmers would do it from a practical standpoint; that he doubts personally that the individual farmer would notice the effect of an inch taken from the flood water, but in the aggregate over the entire plane he knows that it would be a material factor; (897) that the testimony of the farmers that the floods normally varied from seventeen to twenty-five feet would be particularly applicable to the main flood plane, which lies south of (898) Windsor Locks; that in surveying and measuring, as testified to, he included the flood areas totaling 13,000 acres (including marsh

land not cultivated) in the state of Connecticut from the state line to Middletown which would be inundated by the Connecticut River; that he did not include a material acreage south of Middletown which is so much affected by tidal conditions that it was not included; that a twenty-five foot flood would be three hundred inches above zero at the Hartford gauge; that three inches off would be one per cent. of that level, but it would not be one per cent. of the level of the flatter portions of the flood plane: (899) that on a smaller flood of seventeen feet a diminution of three inches would reduce the flood stage one and one-half per cent substantially; that commonly bottom lands are higher closer to the river, and fall off as you approach the higher lands because when the flood rises to a higher level the heavier, sandier sediments are dropped out first as they come back from the center of the channel where the swifter (900) current is, and as it recedes backward toward the high land there is less current, less rampy current and finer sediments to settle out; that the proportion of the heavier sediments is always greater as far as the bulk is concerned than the proportion of the very fine sediment; that the river is continually filling up the land nearby on each side, and there may be some cutting at times; that the Connecticut River in Connecticut is, to a certain extent, deltoid deposit because where it reaches Hartford it begins to strike the tide, so consequently the current slows down very rapidly; and for that reason, during flood stages, it dumps its load, and eventually will fill up a great deal more than it is; that, from casual observations, he found instances where some stones and boundary markers were entirely buried and others had to be put on top of them, one in particular across the river from Hayden's Ferry, where a stone monument had been practically buried six feet; that a granite monument had been buried over one hundred to one hundred fifty years since it was put there, so that now it was only a foot and a half above the surface; that was relatively near the river; that the filling up is greater nearer the river; that we cannot say the sediment is uniform all over; (902) that there is quite a material soil varia-

tion in the meadows, some soils are heavier and some are sandier; that the crops varied somewhat with the amount of rainfall, the character of the season, and the amount of sediment that they received; that they get a good crop every year with land which is regularly inundated; that the higher lying areas yield a lighter yield; that those higher areas are frequently more sandy; that he cannot say absolutely that that is the only factor; that the seepage of water from the uplands of the river has an effect; (903) that the seepage from the uplands comes to the greatest extent in early spring when the frost comes out of the ground; that this is prior to the period of flood here in Connecticut; that in reality that is what causes the flood; that it doesn't get down here and get over the bottoms for a couple of weeks or a month after the frost has gone out of the ground here in Connecticut; that the first crop of hay varies somewhat from the latter part of June to the first of July; that they come onto the second crop in the fall; that the second crop is dependent, as far as moisture is concerned, upon rainfall during the summer, but not as to fertility; (904) that if one had a dry summer he would get a smaller second crop; that was the case in 1929 when there was a very dry summer; that he thinks the farmers testified the day before that the second crop was rather light in 1929; that the upland yield is perceptibly lighter than it is on the meadows; that the yield of hay, as testified to by the farmers, is higher than he would have put it on the average, but they knew more about it than he does; (905) that it is materially heavier than the census figures given for Hartford County, which is about one and one-half tons per acre; that the census figures include upland and meadow; that he agrees with the other witnesses that the inundation of the meadow lands improves the crop of grass; that they have made a very careful study and that with experiments and data he has reason to believe that it is so; that it is due to the fact that the sediment contains more available fertility than would be the content in the soil that is left there after it has been growing crops for a period of years; that they have made analyses of five or ten samples of fresh flood sediments collected soon after

the spring floods, and compared those analyses with twenty-five soils from the flood plane that (906) have been there for several years, and had been built up there, and also compared these with twenty-five upland soils that never received any sediment; that he found that the fresh sediment was noticeably higher in organic matter, humus and nitrogen, than the older soil which they built up; that they found very little difference in the phosphorus content; that the sediment is deficient in phosphorus the same as the soil which it forms; that they found that the potash content of the sediment is somewhat higher than the soil which is forming it; that the main increase is in the nitrogen; that there would be some increase in potash; that another factor is that the acidity of the soil is not quite so great; that the material that is brought in is not so sour or so acid as the soil upon which it is deposited; that he attributes the nitrogen to sewage to a very slight extent, but the amount is not great enough to attribute much of it to sewage; that it contains only about four or five per cent. (907) organic matter, and consequently must come from the erosion from the fields and the farms and other lands all over the Connecticut River basin; that as compared to before the war there has been a marked increase in dairy production in Connecticut; that taking the state as a whole he believes that the farmers are going to grow their own hay more rather than go out in (908) the market and buy it; that they are growing better hay on their farms as a result of improved practices, and consequently there is perhaps a little less general demand for hay than there has been before; that the prices for hay have been a little bit lower for the past year or so, but he does not believe that that means anything in particular, perhaps due to the general decline in agricultural prices; that he hardly believes that the decline in prices is a measure of local demand; that hay is brought into Connecticut from western states; that the hay grown on those meadows is a very good quality of grass hay; that it is not comparable to alfalfa hay in protein content as a dairy food, but it is a good quality hay; that the farmers testified to that yesterday and scientific results as far as

analyses of those particular kinds of hay grown in those particular conditions bear it out; that it is equally as good as timothy; that there has been less change in improved methods noticed on these meadows regarding the raising of hay than in almost anything else that is grown in Connecticut, which is probably due to the fact that they can go ahead and get good crops without putting up any money in the way of expenses, so they haven't felt (909) a demand for them; that he would not be able to give an idea of how deep a layer of silt three inches of flood water would deposit; that it would depend very largely on the way the currents were coming; that it might, on some areas of the flooded plane, if that three inches just happened to be just enough to go over some little rise in the land, give a sufficient amount of inflowing water to wash back the sediment and further disburse it widely which would make much more of a difference than if it were absolutely static water in which you would only get the amount of sediment that would drop from that amount of water and you would get no replacement of water; that if it was a flood twenty-five feet in depth the greater portion of the silt would be carried in the upper layer. Most of the sand would hug close to the bottom but the silt and clay would be sustained in the water relatively (910) uniform if there was much movement; if the movement were slow the silt part would settle out rather rapidly and the fine clay perhaps not settle out for days; that the value of a clay is improving the physical character of soils which are too sandy, and it is necessary to have a moderate amount of clay in the makeup of the soil.

BATTERSON'S TESTIMONY

HON. WALTER E. BATTERSON, Mayor of the City of Hartford, a witness for Connecticut, testified: (1225) That he has been Mayor of the City of Hartford since April 1928; that he was Mayor of the city at the time the special act was passed giving the Board of Aldermen and the Street Board

authority over the South Meadows, so-called, and authorizing the City of Hartford to issue bonds for the construction of a dike; that he recommended the passage of the legislation and appeared before the legislative committee to secure its passage; (1226) that the reasons for this Act were definitely understood; that the question of the additional $500,000 which was requested from the legislature was because of a disagreement as to the cost of the dike, and it was decided to play safe and ask to increase the bond issue; that there was nothing down on the South Meadows to protect until the development of aviation.

So far as any advocacy that he personally made in connection with the dike and its building, was predicated solely upon the desire of the present administration to see that the land was developed as an aviation center in order that Hartford might attract to itself the aviation industry; (1227) that the aviation field is known as Brainard Field, located on the banks of the Connecticut River, so as to use land planes, amphibian and sea planes; that they have an air mail station and a unit of the National Guard located at this field; that the Pratt & Whitney Aircraft Company have planes there; that there has been no demand in Hartford for a great many years for this dike as a protection against inundation in that (1228) portion of the City of Hartford; that the only portion of the City of Hartford that there has been a demand for protection from inundation has been the northerly section known as Commerce Street Dyke for which there has also been appropriated money in order to protect the Commerce Street and the State Street section of the city, but there has been nothing to warrant an expenditure of money in the South Meadows until our building of the field and our desire to make that field accomodate industry that he felt would be attracted to the city; that Pratt and Whitney have built a plant, as have also Chance and Vought, across the river since the agitation for the dike began; that it is his opinion that those concerns might have located on this side of the river had the city acted more quickly in regard to building the dike; that there are twenty

concerns or more in Hartford today that are engaged in the manufacture of airplane parts; (1229) that the object of the dike is to protect and save the field from inundation from the Connecticut River; (1230) that a dike on the northerly side of the city protects practically the entire business section of the city from Commerce Street north to State; that it is inundated in all floods of a certain height, and it is hoped that the dike will prevent any inundation in the future; that the area which the dike south of the city on the south meadows would protect is a considerable area and has been waste land with no development except a few squatters here and there; that it is hoped to build it into the industrial development of the city; (1231) that all this area is not to be devoted strictly to an aviation field; that he hopes that surrounding the field that industry will develop; that he thinks there are 480 acres now that the city owns in connection with this particular field and that he hopes that at some future time a sewerage disposal plant may be located there; that he doesn't know the total area that is going to be reclaimed from the (1232) inundations after the dikes are finished, but that it is a considerable area; that it is more than 480 acres and is easily 1,000 acres; and possibly even more than that; that the Colt Patent Fire Arms Company is located within a half mile of the aviation field; that it is on a higher level although it looks to be on the same level; (1233) that Colonel Colt built his own dike to keep the water out; that this plan of building dikes was first talked about before the War—about 1918; that there was no aviation field at that time; (1234) that he now expects that dikes will be built and that the water will be kept out.

POLLUTION

DR. CHARLES-E. A. WINSLOW, a witness for Connecticut, testified, (503) that he had made special inspections of the Connecticut River and aided in the selection of the various sampling points, and in cooperation with Dr. Rudolfs planned the methods of analysis to be used, particularly those relating to bacteria; that he went over the technique of the examinations and the records with the employees of the State Department of Health who did the actual work, and examined and summarized and tabulated the results, that so far as the chemical technique is concerned, all that he did with the chemical data was to make certain summaries of the results of the dissolved oxygen determinations; that they used in this study, as a measure of pollution from a bacteriological standpoint, the colon group of bacilli; that those are bacilli which are characteristically found in the human intestines; that it is a large group; that certain types of this colon group of organisms are found also on grains and in soil and therefore the present study was confined to the particular kind of colon bacilli, the bacterium coli which is characteristic of the human intestines; that these results (504) reported by him refer to the bacterium coli which is used as an index to sewage pollution, because the chief source from which these bacilli enter the water is domestic sewage, and their numbers in the stream vary with the amount of sewage in the stream; that these organisms are determined in the most direct method by making plate cultures; that these are made by pouring into a shallow glass dish a small amount of melted jelly in which bacteria will live, then adding a measured amount of water, one cubic centimeter, which is about 15 drops, or a fraction of a cubic centimeter, a tenth or a hundredth part, and then letting the jelly with the water mixed with it, harden, so that as the jelly sets, each bacterium is fixed at a certain point and imprisoned in the jelly; this jelly is suitable for the growth of the bacteria, and each bacterium that can grow begins to grow in that and multiplies, and inside of 24 or 48 hours a

little colony perhaps as big as the head of a pin or larger is found; that each of these colonies represents a single germ put in originally, and so, by counting these colonies, the number of single germs that went into the mixture can be told; that that is essentially the method relied upon; that the particular medium used is what is called the eosin-methylene-blue-agar; that this is a medium on which the colon group will develop and on which one can recognize by inspection the characters of the colonies of the true bacterium coli; (505) that they have a peculiar color and appearance, so that these results all represent counts of the number of bacterium coli in measured amounts of water; that the general purpose of his investigations from the public health standpoint was to determine the character of the water at the Massachusets-Connecticut state line, to see how polluted it was, with a view of determining the possible effect thereon of alterations in the flow of the stream; that as far as these bacterial counts are concerned, his results would indicate whether the water was suitable for bathing and whether it was suitable for drinking, either as it stands or with subsequent treatment; (505-506) that the number of colon bacilli would not have any particular bearing on the question of nuisance which would be indicated by the chemical dissolved oxygen studies. (507) (Exhibit C-21) shows the average numbers of bacterium coli by weeks at the state line, and the way the weeks are indicated requires a little explanation; that the week numbered "1" in July is the first week for which we have such an analysis in July; that it really is not the first week in July, but the week that began July 8th, in 1928, and July 7th in 1929, that thereafter, the same principle is followed,—the first week in August began on August 5th in 1928 and August 4th in 1929; that is, the weeks are arranged in order in the month, and numbered in that order but the actual work began in each case, on the 8th or the 7th of July, and the table gives continuous weekly averages from that time on; that the table shows numbers of bacterium coli per cubic centimeter; (508) that the graph (Exhibit C-20) was plotted directly from these figures on Exhibit C-21 and

that the weekly averages are, in general, between 200 and 400 bacterium coli per cubic centimeter; that in only one week did this number fall below 200, that 184 were recorded for the last week in July 1929, that for six weeks the weekly average was between 400 and 600; that three times it went over 700, in the fourth week of August 1928 when it reached 792; the third week of August 1929 when it reached 756; and the second week of September, 1929 when it reached 979; that fourteen individual counts during the first year and twelve during the second were over 1,000; that ten of the fourteen high counts in 1928, were at the east sampling point where the sewage of Springfield is most concentrated; that during the first year these samples were taken just as the chemical samples were taken, three at the state line at three places across the river; that during most of the second year the chemical samples were taken as before, but the bacterial samples for the second (509) year were all taken from the center of the stream at the state line, not at the mouth of any sewer; that there are various standards by which one may judge a stream; that obviously the Connecticut River is not suitable for drinking, without treatment; that the standard for a water for drinking is one colon bacillus in one hundred cubic centimeters of water, that no surface stream meets that standard, without treatment; that the water could be used as a source of water supply if it were properly treated; but that it is beyond the limits generally considered safe for treatment by filtration and chlorination alone; that according to generally accepted standards, it is a water to be first stored and then filtered and then chlorinated; that for bathing it is already distinctly unsafe; that the standards for water for bathing, established by different observers and different State Commissions, vary from four to thirty colon bacilli per cubic centimeter, and the Connecticut is away above even the highest of those standards; (510) that it would be possibly to purify this Connecticut River water for drinking purposes, providing one had storage, filtration and chlorination but that the cost would be high; that Streeter of the Public Health Service estimates that for every increase

of one hundred colon bacilli per cubic centimeter the cost of the treatment goes up about ten dollars per million gallons; that in other words, the more polluted the water is, the more colon bacilli it contains and the more elaborate must be the treatment, the more chemicals must be added, and so forth; that to his knowledge the water of the Connecticut River below the State Line has never been used for drinking purposes, except that twenty-five years ago in Hartford it was used for drinking water (511) during the winter months at which time their upland reservoirs used to freeze up and water was drawn directly from the river and that the people of Hartford suffered from typhoid as a result; that the river water was used without storage and without filtration and without chlorination; that it wouldn't be possibly today, but that was the case twenty-five years ago, and they did have severe typhoid epidemics as a result, just as they did in Lawrence; that he has analyzed the results with regard to dissolved oxygen; that speaking about the last table which Dr. Rudolfs read into the record, showing the dissolved oxygen by months for the years 1928 and 1929, in 1928 the flows remained throughout pretty high; that that was one of the wettest summers in history, in the twenty-four years of which there is a record; that the flow of the river was very high; (512) that his impression was that it was a little more than fifty percent, somewhere between fifty and sixty percent above the average; that in 1929, which was a year very slightly below the average, there is a very different picture; that aside from those general averages, in seventy-nine different instances there were individual values of oxygen saturation below 50 per cent; that on July 27 there was a value of 28 per cent registered; on August 13, a value of 26 per cent; September 4, values of 28 and 27 per cent; on September 10, 16 and 18 per cent; that these very low values were always at the central and east sampling points where they were affected by the sewage from Springfield; that the sewage from the City of Springfield is the principal immediate source of pollution, and that it finds its way along down the east bank; that streams in a river don't mix very rapidly or completely, and in all our

work we always found that the worst was at the east and then the middle and then the west bank; that the same would be true with reference to sewage of other cities, but in that particular case I interpret that as due to the fact that the sewage of Springfield tends rather to hug the east bank, that the east shore of the river is more polluted than the west shore (513) that the really significant results are shown in this Exhibit 18 of Dr. Rudolfs', because that shows the result by days; that he thinks in a case of this kind averages are likely to mislead a little, because if a nuisance is created through a certain week or month, even if general averages are good, it is a real fact, that the crucial time is in the fall when the river flow is low and at that time as exhibit 18 indicates, in 1929, in the first ten days of September, the oxygen was so low as to be oscillating back and forth pretty close to the demand for oxygen; that in other words, during that ten days the stream was in a border line condition in which any substantial removal of oxygen or water containing oxygen would have thrown it completely over the line, that was the time when these results of 16, 18, 24, and 26 per cent saturation were obtained; that it is perfectly true that if there is any oxygen present in a given volume of water at a given moment there will not be any nuisance unless there is a sludge bank underneath it; but that his experience indicates that if the condition is as close to the line as that, that at certain points of slow flow and shallow water (513) and sludge there is likely to be (514) a serious nuisance, that is why he feels justified in saying that a dissolving oxygen content much below 50 per cent saturation indicates rather a ticklish situation and certainly any substantial removal of oxygen above that present would, during a period such as this, have pushed the thing over the line, exhausted the oxygen completely and produced a real nuisance; (514-517)

Q. Now, you are acquainted in a general way with the Massachusetts legislation as to the abstraction of water authorized under that legislation of Massachusetts? A. In a general way, yes, sir.

Q. You are acquainted with the effect the restrictions imposed by the War Department have upon the Connecticut River at the state line, assuming they are complied with? A. I don't think that the change would be sufficient one way or the other during the summer months to be detected by any methods at our disposal, either way.

Q. It doesn't make any difference whether it is the Massachusetts legislation or the restrictions of the War Department? A. Just look at it from a broad—let me try to look at it not as an expert, but from a broad common sense standpoint at the beginning. Say you are putting in or taking out something well under five per cent. Now, then, none of these methods we are using on the river would check on samples taken a half hour apart within five per cent. In other words, I cannot conceive that the effect of these differences and the change in the condition at the State line could be detected by any means at our disposal.

Mr. Warren. What do you mean?

The Witness. I mean if you take out five per cent of the water in the Connecticut or five per cent of the oxygen, or if you put it in, put in five per cent more or take it out of that now reaching the state line or if you could take the river just above the state line and had a magnet and could pick out five per cent of the oxygen or put in five per cent more of oxygen, nobody would be able to tell the difference. If the experts on both sides of this case were there before and afterwards I doubt if they would be able to obtain results that would show a difference. If you take out 10 per cent, I am inclined to think you could probably find a damage or a benefit, depending on whether you are putting it in or taking it out. Then if you got 20 per cent, I am rather sure you would have a rather definite and appreciable and serious result if you diverted out of this flow. This flow was around 3400 million gallons average during that summer. Now, if you had taken out 500 million gallons out of that thirty-four, 500 million gallons of pure water, I think there would have been a very serious effect on the water at the state line and it would probably have had a greater effect on the oxygen, and would have probably been sufficient to push that river

over the danger line and make it an open sewer instead of a stream. But if you took out four hundred, you could probably detect it anlytically; it might be a little less pure. If you took out a hundred thousand or two I don't think that even a group of eminent experts could detect with any certainty any effect. We can say that every quart we take out makes it worse or every quart we put in makes it better, but within the limits we can use in analyzing you would have to have 10 per cent change, let us say, one way or the other before you could get anything that would be really significant.

Q. So that so far as the actual condition of the water is concerned it isn't going to be materially affected one way or the other? A. I don't think so.

Q. It can't be any better and you don't think it would be any worse? A. I don't think either diversion under the War Department ruling or diversion under the Massachusetts statute, as I understand it, would make any detectable difference in the water at the State line.

Q. At present. A. At present.

Q. Now, then, assuming that there is a normal growth of population and industry between the State line and Holyoke, including the city of Holyoke, will that have any increased or make any increased demand upon the water during the next ten years for oxygen? A. Why, yes. The more sewage and the more industrial wastes one puts into a river, the more oxygen is needed to take care of it. The condition of the river depends upon the balance between these two things.

Q. So that if the abstraction of water either under the Massachusetts legislation or under the War Department restriction, becomes finally settled as a permanent thing, then would you say that the increased growth of population between the State line and Holyoke would tend to create a worse condition and go over the border line during the next ten or twenty years? A. I am not perfectly clear as to that. You mean irrespective of diversion or—

Q. The diversion is out. A. Yes. The condition of that river will in all human probability grow worse on the average, aside from flow variations, from year to year, with the increase in population unless somebody takes steps to purify sewage and industrial wastes.

Q. Now you say that if there was a contribution during the low flow period of perhaps 10 per cent of oxygen from pure water it would have an appreciable effect for the good of the stream at the state line? A. I think it would. I think you would probably find that that was a detectable difference.

Q. So that if the compensation from the diversion of the Ware and Swift Rivers amounted to 10 per cent of the oxygen in spite of the amount which is authorized to be released under the War Department's restriction, you would have a substantial benefit instead of a situation which does not change the present situation? A. I think anything that added 10 per cent to the pure water in the Connecticut River would benefit it appreciably.

Q. In other words, as I understand it, you have a condition at present where the stream is approaching a border line, where it might go either one way or the other, depending upon whether you added a substantial amount of water or oxygen to the stream or whether you took a substantial amount away? A. Yes, I think the Connecticut River at State line in the autumn of a fairly average year is what I should call on the border line of nuisance.

The witness testified that he thinks the Connecticut River at the state line in the autumn of a fairly average year is what he would call on the border line of nuisance; that to take water out of the (518) Connecticut River between Hartford and the state line, for domestic use would require the treatment that has been suggested, that is, it requires storage and filtration and chlorination; that the water could be used for drinking with storage plus filtration, plus chlorination, not with filtration and chlorination alone; that assuming that there was storage and the filtration and the chlorination you could produce a water which would be suitable for drinking purposes for the people of Hartford, but it would be quite expensive; but that it could be done and he thinks it could be made comparable with the water which they have now; that this is a hypothetical question, that he doesn't know it could be stored from a practical standpoint, but assuming it could be stored for sixty days,

he thinks it would be just as good and probably safer than the present surface supply.

(520) Q. Supposing that the flow of the Swift River during that period was 1.3 per cent of the Connecticut's flow at the state line, would that amount fall within the quantities which you described as negligible and non-detectable? A. I think it would, sir, yes.

Q. And as I understood you, neither you nor the experts on our side would be able to determine with any satisfaction to themselves or to yourself, what the effect of that was, that addition or subtraction? A. Assuming, it to be 1.3 per cent of the total flow of the river?

Q. Of the total flow of the river? A. Yes; I think that it is true.

Q. As I understood you, that would be true probably up to a contribution or a diversion of about five per cent? A. I should say somewhere around there, yes.

Q. And after five per cent it would become detectable and at 10 per cent I think you stated that it would be detectable? A. Yes.

Q. And at 20 per cent it would not only be detectable but serious? A. Yes, sir.

Q. And that applies with reference to the amount of oxygen in (521) the water? A. Yes, that applies to water which is relatively pure. I am assuming in that the water diverted is water diverted at the upper part of the stream before it is heavily polluted. If you take out one-fifth of the water at the state line you would not change the percentage relations at all.

Q. Would you say that that same conclusion was true as regards the public health? A. Well, yes, I should, because you would have to have an enormous change in quality on the one hand and an enormous improvement, to make the river safe for bathing. You would have to have a very large change for the worse to make it impossible to purify it by storage, chlorination or filtration. I should say then that a change of five per cent either way was not of practical moment.

Q. Either as regards the purity of the water or the effect of the water with respect to public health? A. Yes, sir.

Q. You made these investigations at other points besides the State line? A. Yes, sir.

The witness testified that the condition of the river improves between the state line and a point above Hartford; that it improves very rapidly immediately below the state line, as a result of the dam at Thompsonville; that there is long storage and aeration and there is very marked purification on the way down from state line to Connecticut's sampling station F, above Hartford; (522-523).

Q. How much better is the water when it gets to Hartford before the Hartford sewage enters it, than it is at the state line? Can you tell us that? A. I have results both for dissolved oxygen and bacillus coli, if you would like them.

Q. I should like both. A. In 1928 the dissolved oxygen averaged, you remember, 74 at the state line. It rose to 86 below Windsor Locks.

Q. That you would call pretty good,—86? A. Excellent. In the second year it rose from 54 to 79 in the same distance.

Q. Seventy-nine would stand pretty high, wouldn't it? A. That is good, yes.

Q. That was the average for the period? A. That is the average for the period in each case. Then the dissolved oxygen below the dam dropped somewhat, for the station above Hartford, dropped from 86 to 72 in the first year, and from 79 to 69 the second year. The bacteria, on the other hand, were lowest in both years at the station just above Hartford. They take longer to die out than the oxygen takes to be reintroduced by aeration. Their numbers fell from 395 at the state line to 72 above Hartford.

Q. Would that figure be reasonably satisfactory or is that high, as compared with other rivers? A. That is a very good river figure for a river in a settled area, yes.

Q. If there would be any determinable difference, how much difference do you think there would be in the cost of purifying the Connecticut River at Hartford, in the way you have suggested, by storage, filtration and chlorination, before and after this Ware and Swift River diversion? A. I have tried to indicate that the

difference due to the abstraction of one per cent or two per cent of water is so slight that it cannot be measured in any concrete way. It is a purely theoretical damage or advantage when we are within these limits.

Q. For any purpose? A. For any purpose that I know of we cannot determine within one or two per cent;

(524) The witness testified that he has no opinion as to the effect of a diversion of one or two per cent on navigation, power or fish life but is confined to public health; (525-526-527) that the following streams in most of which analyses were taken at points in the stream that were used or proposed to be used for water supplies, these streams being reasonably comparable with the Connecticut River; that these averages are for a year, and recent years in each case;

	Colon bacilli per cubic centimeter
Mississippi, above Minneapolis	13
Maumee, at Toledo	20
Allegheny, at Pittsburgh	21
Ohio, at Louisville	22
Grand, at Grand Rapids	26
Delaware, at Trenton	29
Ohio, at Cincinnati	30
Mississippi, at St. Louis	31
Maiden Creek, at Reading	42
Merrimac, at Lawrence	42
Mahoning, at Youngstown	54
Schuylkill, at Philadelphia	59
Connecticut, above Hartford	68

The Connecticut above Hartford is the best point in the river.

Missouri, at Kansas City	159
Hudson, at Albany	194
White River, at Indianapolis	225
Connecticut, at the State Line	378

(527) that almost all of these figures other than that for the Connecticut River, include the total colon group so that would

tend to make them higher than ours which include only the true bacterium coli; that if he had included all the bacterium coli count the result would have been higher on the Connecticut River; that in study of water supply proposition, the whole colon group is used because no foreign matter whatever is wanted, but for pollution he thought it best to use specifically the intestinal coli; that the following figures are for the per cent of dissolved oxygen; the Hockanum River varied from 92 at best to 58 at the worst; the Raritan in New Jersey in 1927 varied from 89 at best to 52 at the worst; the Naugatuck in Connecticut in 1919 varied from 98 down to 50; that the Massachusetts results general do not show dissolved oxygen but in 1900 the Merrimac went down to 32; that the Connecticut in 1929 went down to 16, a single observation; the Mississippi in August, 1929, varied at different times from 100 per cent saturation to 10 below Minnesota and St. Paul; some August figures in which the Connecticut in 1929 is comparable with a series of Ohio streams, streams tributary to the Ohio River, a public health service study:

	Colon bacilli per cubic centimeter	
Tennessee River averaged	88	in August
Scioto	87	
Beaver	85	
Ohio, a number of stations	83	
Alleghany	82	
Licking	82	
Cumberland	79	
Monongahela	76	and the
Connecticut during this past August	51	

(530) that the Connecticut for August 1928 averaged 70 at the State Line; that the average above Hartford for August 1929 was 68 and in 1928, 70; (531) that conditions can be improved by sewage disposal plants; that it is possible to take the sewage of a city and turn it into drinking water; that there is one plant on the New York City watershed where the purified sewage of Mt. Kisco is purer than the brook into which it flows; that if the sewage in the Connecticut River should in the

future become serious because of the increase in population or for any other reason, the danger would be practically eliminated if the cities along the river adopted sufficiently elaborate sewage disposal plants.

DR. WILLEM RUDOLFS, an expert witness called by Connecticut, testified (418) that his investigations included as far as the character of the stream is concerned and the character of the pollution mainly three tests in addition to some minor ones; namely, dissolved oxygen, biochemical oxygen demand, and bacteriological examinations; that in addition, more complete chemical tests of the water were made at less frequent intervals; that two forms of pollution were considered, one coming from human beings, domestic sewage, and the other pollution coming from industries, industrial waste; that the investigation included domestic sewage, industrial sewage and sludge deposits in the stream; that sludge deposit is that material discharged either by human beings or industries that is heavier than water and if the velocity of the stream is insufficient, that material will settle, forming first in (419) quiet places and around bends, in banks, slight deposits which will accumulate later on; that the first deposits usually occur below sewer outlets; that the rate of flow of the stream has something to do with the existence of these sludge deposit beds; (420) that the amount of water has some connection with the uncovering of these sludge deposit beds because if there is very low water, naturally, the sludge deposits will come above the water line; that the effect is that these sludge deposits will come above the water line; that the effect is that these sludge deposits are susceptible to being decomposed and naturally the bacteria present in the sludge beds continue to work, and all kinds of foul odors begin to occur; that they selected about fifteen sampling places in the Connecticut River below the Massachusetts-Connecticut State line, and seven above the State line; that one was at the State line; that samples were collected at a given time of day, put on ice and transported to the

health department laboratory in Hartford and analyzed, except that a portion of the analytical procedure had to be carried out in the field, namely, that for dissolved oxygen; that otherwise the time of transit might make some difference; that in the laboratory the analysis was completed; that in order to determine the hour (given time of day) for taking samples, samples were taken over a period of several days, one and one-half hours apart, three samples across the river at mid depth; that the results were plotted over these several days and the average for the whole river at that particular point was determined; that the point on the curve which was nearest the (421) average plotted on time gave the average condition for the whole day and so the particular hour of the particular day which would give the average condition for the stream for a whole day was found; that if but one sample was taken, say in the middle of the stream, the velocity and the volume of water might be different from the places nearer to the banks, so samples were taken at a place one-quarter from the east bank, one-quarter from the west bank and another sample in the middle of the stream, so that there were three samples across the stream and all taken at mid-depth, mid-depth being half way between the bottom and the surface; that the samples were taken at mid-depth because if they are taken near the surface the conditions might be a little better than the average due to reaeration conditions; that if they were taken close to the bottom the results would be a little worse because there might be a sludge deposit and the oxygen demand might be greater than the average of the stream; (422) that mid-depth gives the approximate or average condition of the stream; that dissolved oxygen is the quantity of oxygen which is dissolved in water at a given atmospheric pressure in a given amount of water; that pure water, for instance, absorbs more oxygen than impure water or sewage; that impure water is capable of carrying only a given quantity at a given temperature and given atmospheric pressure; that when water contains all the oxygen it is capable of absorbing when intimately mixed with air at a specific temperature and pressure, it is said to be saturated;

that for instance, at about 50 degrees Fahrenheit and a definite pressure of 29.92 inches barometric pressure, water contains 11.33 parts per million of oxygen; that polluted streams are rarely saturated with oxygen, and the results are, therefore, often expressed in percent saturation; that if the percentage of saturation is low the stream is heavily polluted, and if the saturation is below a given quantity, nuisances might occur or first the fish life might be interefered with or affected; that that is the significance of the expression percentage of oxygen saturation; that another expression of oxygen saturation is direct in parts per million of oxygen dissolved; that from this can be calculated, provided the temperature and the flow of (423) water are known, the number of pounds of oxygen present in the water at any given temperature; that parts per million means that if there is a million pounds of water containing one part per million this water would contain one pound of oxygen; that if there are a million gallons of water with one part per million oxygen there would be 8.33 pounds of oxygen in the water; that biochemical oxygen demand is the amount of oxygen which is consumed by impurities in the water in a stated period of time and at a (424) definite temperature; that five days' oxygen demand at 20 degrees Centigrade (68°F) in our studies is generally used; that from that can be calculated also 10 and 20-day demand, or whatever is wanted; that the biochemical oxygen demand test is the most important test in gauging the conditions of the stream; that by studies of biochemical oxygen demand the load which is placed on the river by individuals, towns or industries can be determined, and the progress of natural purification which takes place in the river when it flows down, can be shown; (425) by "load" is meant the amount of polluting material put in the river; that from studies it is known that the excretion of soluble and solid material from humans has a definite demand for oxygen; that each day the biochemical oxygen demand of domestic sewage is around two-tenths of a pound of oxygen per person contributing; that the population equivalent for any given quantity of sewage, either discharged or

already present in the river, can be calculated by biochemical oxygen demand; that the samples at the Massachusetts-Connecticut State Line were collected at 8 o'clock in the morning during the year 1929; that the results obtained were average conditions for that day, at that particular point; that during 1929 these samples were collected daily at the State Line from July 8th (426) to September 14th; that in 1928 they were collected from June 17th to November 18th (427) at the State Line; that during the period of July 8 to September 14, 1929, the percentage of oxygen saturation was from 20 to 29 one day; eight days from 30 to 39; sixteen days from 40 to 49; twenty days from 50 to 59; seventeen days from 60 to 69; six days from 70 to 79; and one day from 80 to 89; that the least at any date observed was 23 per cent saturation, while the maximum was 83; that the average for the whole period was 54 per cent saturation; that the number of days the saturation was below 50 per cent was as follows: out of the 69 sampling days, 25 times the saturation was below 50, or a little over one-third, namely, 36 and a fraction per cent; that this per cent of saturation, means the proportion, compared with what is called complete saturation of the water at that temperature and place; (428) that this is a direct indication of the degree of pollution; that the smaller the percentage of saturation, the greater the pollution; that if there is 20 per cent saturation, then the pollution is much greater than it is when it is 40 or 60 percent; that Exhibit C-16 shows that on July 8, 1929, there was a definite saturation, but on July 21st it was lower; that this shows how the pollution condition progressed during the summer plotted in weekly averages, for convenience; that there was a progressive reduction in the percent of saturation in the summer months between the week of July 8th to the week of September 8th, 1929, (429) finishing with September 14, 1929; that the values are higher on some days of the week than on others but that the Exhibit C-16 shows weekly averages; that Exhibit C-17 is a summary of oxygen results expressed in parts per million for that same period, showing the average for the whole period, the number of samples at

which (431) certain saturations occurred; also the average dissolved oxygen in parts per million, for a number of samples; that the average temperature conditions, or the average temperature of the water during the summer was 22.2 degrees Centigrade which is about 72 degrees Fahrenheit; that pure water contains when saturated, 8.8 parts per million of oxygen at 20 degrees Centigrade, or 72 degrees Fahrenheit; that even at the highest temperature observed in the river, (432) the water, if it had been pure, would have contained at least eight parts per million; that the average saturation was only 54 per cent; that in 82 individual cases the dissolved oxygen was below four parts per million; on 44 occasions, below three and a half; on 17, below three parts per million, while in two samples the oxygen was below two parts per million; (433) that as to the relation between dissolved oxygen and biochemical oxygen demand:

> "organic matter present in sewage or industrial wastes is in a state of putrefaction or susceptible to putrefaction. As soon as the putrescible matter reaches the river, it begins to use up the oxygen in the water. Since the oxidation of the waste is brought out by biochemical activities or agencies, the sewage and waste are said to have a certain biochemical oxygen demand. The sewage from one person is found to have a 20-day oxygen demand of about two-tenths of a pound of oxygen per day. Industrial wastes vary greatly in strength, (434) but on the basis of the pounds of oxygen demand, it can be calculated into population equivalents; knowing the amount of oxygen required by a certain volume of industrial waste, knowing the oxygen demand of a certain person, it is a simple arithmetical calculation to state the population equivalents. In industries, as I said, they vary greatly. Some of them have a small oxygen demand, others great. There are above the State Line quite a number of wool-scouring and dyeing industries and the amount of product produced per year is in direct relation with the amount of polluting matter. So if we had a thousand pounds of product produced per year, we know that it has a population equivalent, according to the United States Public Health Service Bulletin 171, of

> 4.15 persons. We have used a slightly lower figure. That means that it a particular plant which is in Massachusetts, where they have about seven hundred employees, the population equivalent of that industry is 35,000. So the waste has a definite oxygen demand and sometimes considerably greater than the persons".

That this is strictly industrial population equivalent, although industrial wastes might be mixed with the domestic sewage; that if the amount of oxygen in the river is insufficient, fish life is affected, and if the oxygen content is nearing exhaustion (435) odor nuisance begins to occur, even if there are no sludge banks present; that there is a higher oxygen requirement for fish life than to prevent nuisances; that certain fish require more oxygen than others; for instance eel and carp and catfish require less dissolved oxygen than fish like bass, pickerel and trout, which like cleaner water; that the amount of oxygen required by fish like shad is a minimum of 3.5 to four parts per million; that when the dissolved oxygen is lowered beyond this point, the fish begin to migrate, if they can, or if they cannot they begin to suffocate because there is not sufficient oxygen in the water for them to live; that the oxygen balance in the Connecticut river at the State line between September 1 and 11, 1929, is shown on Exhibit C-18; (436) that during a certain portion of the year—September 1 to September 11 is taken—on Exhibit C-18, the amount of oxygen in the river is plotted as a dotted line and the demand of the river is given as a solid line, showing that at sometimes during that period the oxygen demand of the river was the same as the oxygen which was dissolved, so that there was nothing left if all the demand was satisfied; that the pollution was such that all the oxygen should have to be taken out of the river to satisfy the pollution on that particular day; that other days there was more oxygen than was necessary to oxidize (437) all the polluting matter in the river; that at another instance on the 10th there was less oxygen; that on the 4th the oxygen demand and the dissolved oxygen were just equal; so that if all the organic matter had been oxidized on that day

there would have been no oxygen whatsoever in the river; that the difference between the oxygen demand and the oxygen dissolved is referred to quite often as the oxygen balance; that the oxygen balance is oxygen that might be available for further oxidation, as a reserve; that on that particular date if all the organic matter was oxidized by the oxygen in the river it would be all used up, so the demand on the river was equal to the amount available, where at other places there was more than the demand and at one instance there was less than the demand; (438) that in the third column of Exhibit C-17, the average biochemical oxygen demand in parts per million is given as compared with the oxygen dissolved present; that there were 405 samples all told and out of these 405 there were 182 where the oxygen balance—the oxygen available—was less than two parts per million; in 82 cases it was less than one and a half parts per million; in 44 cases less than one part per million; (439) that these are the lowest 182 out of all the 405 samples taken; that 223 had a balance of more than two parts per million; 182 a balance of less than two parts per million; that in a number of cases as given here—in six cases—the oxygen demand was greater than the oxygen available; (440) that this table shows that in six samples of 405 there was no oxygen balance, that oxidation of all the organic matter would consume all the oxygen; (441) that in Exhibit C-19 the upper line shows the dissolved oxygen throughout the summer; that the broken line labeled oxygen balance shows the surplus of oxygen available, and the line labeled b.o.d. is the 5-day biochemical oxygen demand; that fish, in order to live, need an amount of oxygen of 3½ to 4 parts per million, that is where the balance comes in; that there were a number of days that the river was so polluted at the State line that fish like shad had either to migrate or die; that the oxygen balance as shown by the last column (442) shows that the oxygen balance was for a number of instances less than the oxygen required by the fish, if the river was used for oxidation of the sewage polluted matter; that three and one-half to four parts per million are required by fish; (443) that on some days during each of those weeks

it would be greater and some days it would be less, but this would be the average;

> "when the stream has sufficient velocity to prevent deposits and contains some dissolved oxygen, odor nuisances are negligible, but if the velocity is low, if it is lower, as frequently occurs in the summer, so that solids in suspension will settle out, sludge banks will occur and these deposits, first in quiet places and so on, begin to work their way down stream (444) to an extent. Sludge deposits, since they are partly organic in nature, and the bacteria are there, exert a certain oxygen demand on the overlying water or the water that flows over them, and take out the oxygen which is necessary. When the oxygen in the water above is insufficient to satisfy all the demand, then we get conditions where odors begin to occur; we get putrefactive odors, odors like material that is rotten, disagreeable odors. Sometimes when it begins you have at first the distinct sewage odor and that increases gradually. During high flows these sludge deposits may or may not disappear. During the summer the oxygen content of the water of the river is usually low, because it depends on the temperature. The higher the temperature the less oxygen in the water. At the same time the temperature stimulates the bacteria to work faster, so that they need more oxygen. There is less oxygen in the water and there is a greater demand. Then, at the time the flow of the river is also low. You have three factors, the low flow of the river, a great demand, and less oxygen in the water. Then the sludge deposits in the river give you the poorest conditions in the river and give you the greatest pollution in the river, during the low flow and high temperature, and we have sludge banks, all these three factors together." "I said that high flows have a tendency to remove sludge deposits which have deposited during the summer (445) or spring, and have a tendency to remove them, scour them out, if you wish to use that term, or drive them down."

That any flood flow would have a tendency to drive out or scour out that sludge which was retained during other times; that a survey of the river was made trying to find out what the sources of pollution were which had been found to exist at the State line,

and so both an industrial survey and also a survey of the conditions of sewer outfalls and soon was made; that the surveys of industries along the Connecticut River and tributaries south of the dam at Holyoke, consisted of an inspection of the sewer outlets, industrial sewer outlets discharging waste into the water; that very extensive field observations were made; that samples were taken for the purpose of estimating the quantity and the nature of the materials, and so on, and at the particular time when that was done, the textile industry and to a certain extent also the paper industry were suffering (446) from business depression, with the result that in many cases the waste was less than it would ordinarily have been; that fish life depends upon the dissolved oxygen (447) not necessarily on the oxygen balance; (449) that it is the amount of dissolved oxygen that determines the migration or possibly the life of the fish, not the oxygen balance; that the dissolved oxygen requisite for fish is 3½ to 4 parts per million; (450) that the survey for domestic and industrial waste conditions in the river not only included between the State line and Holyoke but extend much further up the river about 320 miles to (451) even beyond the Massachusetts line, into Vermont and New Hampshire, to see whether there were any possible sources of pollution which could contribute to a marked extent to the conditions; that for 1929, the summarized results show that the New Hampshire and Vermont contributing population, which is sewered population, within that drainage area of the Connecticut River, was 73,150, Massachusetts, 407,590; that the industrial wastes of Massachusetts, in population equivalent, was 139,000 people, making a total of 619,740; that the survey was made away up the river, and all of its tributaries, in order to find other possible sources of pollution which were materially effective in any condition existing at the State line; that the survey was made for about 320 miles upstream, above the mouth of the river; that the bulk of the waste was discharged into the Connecticut by the towns of Holyoke, Chicopee and Springfield, with a considerable quantity coming from the Chicopee River, which is a tributary, coming in just above Springfield; that the Ware and Swift

Rivers are tributaries of the Chicopee; (452) that very little industrial waste comes from New Hampshire and Vermont; that by the time it reaches the state line it is all oxidized; that the distance is so long that the oxygen in the water has taken care of it; that the results between the state line and Holyoke show that the amounts of industrial wastes and domestic sewage waste, again expressed in population equivalents, are about 400,000 persons per day, 65 percent of which is industrial; (453) that as to population equivalent, a given quantity of waste can be calculated into population equivalent because how much oxygen is required for a person is known; that one can translate that directly into industrial wastes; that is what we mean; (458) that during the period July 8 to September 14 the average flow of the Connecticut River at the state line in 1929 was 5,050 cubic feet per second; that the average percent saturation of dissolved oxygen was fifty-four, and the average dissolved oxygen was 4.73 parts per million; (459-61) that based upon the average flow for 1929 as 5,050 cubic feet per second and an average percentage of dissolved oxygen during that period, assuming the same conditions to exist as existed between July 8 and September 14, 1929, and taking into consideration the increase in population and industrial growth, that the estimated equivalent population demand, the dissolved oxygen saturation and the dissolved oxygen in parts per million at the state line for each ten years from 1929 to 1970 are: (corrected figures, pp. 537, 538)

Year	Equivalent Population	% D.O. Saturation	D.O. P.P.M.
1929	750,000	56	4.9
1940	900,000	50	4.4
1950	1,080,000	45	3.96
1960	1,290,000	41	3.61
1970	1,540,000	37	3.26

that this is based upon the population for the principal counties contributing above the (460) state line, draining into the river; the counties were, in New Hampshire—Cheshire, Coos,

Grafton, and Sullivan; in Vermont—Caledonia, Essex, Orange, Windham, Windsor; in Massachusetts—Franklin, Hampden and Hampshire; that the basis for figuring those increases in population was the United States census figures for a number of years back; (462) that equivalent population means the population including the industrial equivalents, because there is a definite load on the river and the basis of the figures is the load which the river must carry whether it comes from population or the plants which may exist upon the stream; that taking the river as it was, as a definite flow of 5,050 cubic feet per second, as to whether that was larger or smaller than the usual summer flow, did not very much concern him in these calculations; that he only had two years' actual records of the river; (463) that the condition in the river in 1928 expressed in percentage of oxygen was better than in 1929; that there was more water in the river in 1928; that the reduction in the amount of water in the stream has an effect on the condition of the river; (466) that the extent of the sludge deposits at the state line in October 1929, was about 310,000 square feet with an average of about 1.4 feet in depth, or a volume of 435,000 cubic feet; that the volatile solids amounted to about 1,000,000 pounds, with a biochemical oxygen demand of 108,400, with a population equivalent of 500,000 to be satisfied from the water in the river; (467) that he made two sludge surveys in 1928 but the real investigation was done in the spring and fall of 1929; that one started in April and ended in June, and the other started in September and ended in October, October, or beginning of November, possibly; that in June 1929, approximately the same conditions were found as in October, 1929; that surveys were made north of the state line between the state line and Holyoke; that in the spring a number of sludge banks around Springfield and Holyoke were investigated and the same thing was done in the fall; that using the sludge bed at Springfield, at the lower bridge as an illustration, (468) the area in early summer, in June, was 104,900 square feet, in the fall 178,000 square feet; that the volume in the early summer was 108,000, in the fall 195,800 cubic feet;

that the biochemical oxygen demand in the summer was 54,950 and in the fall was 64,950; that that indicates an accumulation of sludge deposited by the towns there, or thereabouts, with a definite increase in oxygen demand during the summer months from June until September or the beginning of October; that he doesn't think that it can be said that the amount of water which flowed during that period was sufficient to satisfy the demand because the velocity of the stream would have something to do with it; that if solids settled down at a rapid rate, it would take some time before the biological activities are demanding oxygen, so it cannot be definitely stated that the volume of water is sufficient, but that it is assumed that the water was satisfied with oxygen at that particular place, flowing over the sludge beds; that he would say that the sludge beds apparently took out, in addition to the sewage which (469) was discharged and didn't settle, a large volume of oxygen; that when the survey was made the sludge banks were partly exposed at low waters, depending on what day they were seen; that the amounts of dissolved oxygen at the state line shown on Exhibit C-19 represent the amounts of oxygen left after the sludge banks had absorbed oxygen from it; (470) that from an examination of the analyses which was made of the water taken at the state line, in the manner that has been described, the witness' opinion, as to the quality of the water in the Connecticut River at the state line, at the present time, is that it would need considerable treatment before the water could be used as a water supply; that it could be used by treating it; that in regard to fish life, the water at the state line is just on the border line; that in regard to bathing, the river at that place is polluted, and is dangerous for bathing; (471) that "present time" means the period under the condition found while the investigations were being made, (472) which was during the low flow of the stream; (473) that if all over 85,000,000 gallons per day were to be taken from the Ware River and 20,000,000 gallons per day would be released from whatever storage is provided for on the Swift River, and that amount of water is diverted during the summer months, under

conditions as they existed during the period from July to September, 1929, that would have an adverse effect on the condition of the river from the standpoint of sanitary conditions; that any reduction in the amount of water would have an adverse effect; that assuming the restrictions of the War Department are complied with, during a period similar to the period between July and September, 1929, it would probably have no effect (474) upon conditions in the Connecticut River at the state line; that the river would not be any safer to bathe in; that it would not be much better, nor much worse; that it would be possible during a period such as was the period between July and September, 1929—to materially improve the conditions at the state line, if a substantial amount of water was added to the natural and normal flow of the stream; that it would take quite a volume; that there would have to be quite an increase in volume in order to make a material impression; that it would have to be a lot more substantial than that added by the War Department for navigation purposes; (475) that these remarks related to bathing, water supply, fish life; that perhaps it will affect, also the sludge bank formation, because the velocity would possibly increase and the scouring effect would be a little better; but it would have to be a large addition; that considerable would have to be taken out to make very much noticeable difference; (477) that there have been compiled for the year 1928 by weekly averages, the percentage of oxygen saturation, the dissolved oxygen in parts per million, the five-day biochemical oxygen demand in parts per million, the temperatures and the discharge of the river at Thompsonville in cubic feet per second, as follows:—

Week Starting	Per Cent Saturation	Temperature (Centigrade)	Dissolved Oxygen	B.O.D.	Discharge of River
June 17	84	18.2	7.9	2.5	15,900
June 24	85	19.4	7.8	2.2	13,100
July 1	86	22.4	7.6	1.6	15,800
July 8	78	24.6	6.6	1.8	9,770
July 15	70	24.6	5.9	2.0	9,920
July 22	67	23.4	5.8	2.0	10,100
July 29	70	22.5	6.1	1.5	11,400
August 5	67	22.8	5.8	1.6	14,400
August 12	72	24.0	6.1	1.4	11,500
August 19	61	23.5	5.2	1.5	8,200
August 26	79	20.9	7.1	2.0	22,900
Sept. 2	82	19.5	7.6	1.6	15,800
Sept. 9	74	19.2	7.0	1.7	9,070
Sept. 16	84	18.6	7.9	1.6	13,800
Sept. 23	79	15.3	8.0	2.1	9,010
Sept. 30	78	13.5	8.2	2.5	8,170
Oct. 7	76	14.6	7.8	2.8	7,210
Oct. 14 (479)	79	14.9	8.0	2.2	8,850
Oct. 21	83	12.7	8.9	2.3	14,500
Oct. 28	81	8.2	9.6	3.0	9,900
Nov. 4	85	7.0	10.3	2.7	9,440
Nov. 11	85	5.5	10.7	3.2	8,130

The averages for that whole period:—

Per cent saturation	77
Temperature	18°C
Dissolved Oxygen parts per million	7.5
Five-day biochemical oxygen demand parts per million	2.1
Discharge in cubic feet per second as calculated by weekly averages	11,670
As calculated by daily averages	11,640

(480) The averages corresponding to the period of 1929, July 8 to September 14, are as follows:—

Temperature	22.2°C
Dissolved oxygen parts per million	6.3
5-day bio-chemical oxygen demand parts per million	1.7
Discharge cubic feet per second	12,310

12,310 cubic feet per second is the average discharge corresponding to the year 1929, when the discharge was a little over 5,000 cubic feet per second, as he said this morning;

(482) that he did not say that the addition required by the War Department would not make any appreciable difference; that naturally every pound of water that is put in improves the river; (483) that he meant to say that any quantity that is taken out will of course be detrimental and any quantity that is added will be beneficial, but that the amounts added are not so very large, so the improvement will not be very great, in view of the condition of the river at present, because it is badly polluted; that that is what he meant to convey; that suppose there is 5,000 cubic feet per second flow in the river, if 150 cubic feet per second is added it would help; that as to how much, appreciably, that depends upon what meaning is placed upon appreciably; that if by appreciably is meant a very large extent, he would say no; (484) that he figured roughly 150 cubic feet per second is approximately 100 million gallons of water a day; that that would mean a population equivalent of 37,000; that if that much water were added, the sewage of 37,000 more people could be handled by the stream; that those are rough figures and it might be a few one way or the other; (485) that each cubic foot per second would take care of one-one hundred-fiftieth of 37,000 people; (486) that if instead of adding 150 cubic feet per second, 150 cubic feet per second were subtracted or diverted the same results would be obtained, the water being able to take care of thirty-seven thousand less people; that is because it is based on the volume of water containing a certain amount of oxygen; (487) that the water he has in mind is in the state of nature, where you have good water; (488) that the contribution into the Connecticut would not be pure water even though it started pure from the Ware or Swift River Reservoir; (489) that the quality of the water of the Swift River at West Ware is good; that the water of the Ware River at Coldbrook is slightly less good; that the difference is very, very, very small and that they are

both good, potable waters; (490) that the condition in the Connecticut River was better in 1928 than in 1929, materially better; that the average flow at the state line was about two and one-half times as great, during the period; that in 1929 it was 5,050 cubic feet per second and in 1928 it was 12,310 cubic feet per second for the same period; (491) that so far as the Ware River is concerned the diversion authorized by Massachusetts, had it been in effect, would not have affected in any way the water in the Connecticut River during that period, July 8th to September 15th, 1929, if Massachusetts observed the requirements of the War Department; that as to the Swift River, if the order of the War Department had been in effect during that period, in 1929, there would have been more water in the river; (493) that as far as the pollution of the river is concerned, if this water plan is carried out, and if the two orders of the War Department are obverved by Massachusetts, the condition will be an improvement in the Connecticut River water at the State line, under such conditions as existed in 1929; that the improvement in the Connecticut River by this added supply (i. e. the release from storage in the proposed Swift River reservoir) is more with low water; that the addition coming in a period of lowest water is more helpful than it would be in high water; (497) that the weekly average temperature of the water at the State line between July and September, 1929, was for the week beginning July 14th, 23.6; for the week of July 21st, 23.6; for the week of July 28th, 25; the week of August 4th, 22.2; the week of August 11th, 22.8; the week of August 18th, 21.7; the week of August 25th, 21.4; for the week of September 1st, 21.8; and for the week of September 8th and ending the 14th, 21.7; the average, 22.8; and corresponding temperature over the period of the previous year, 22.6; (499-500) that Exhibit D-2 shows that under the requirements of the War Department there would have been, during 1923, an increase or contribution of water from the Ware and Swift during 12 weeks, almost three months, from the beginning of July to the middle of October; that these contributions would have varied from five to 54 cubic feet per second; that assum-

ing that the average contribution was 45 cubic feet per second it would have amounted roughly to one and one-half per-cent of the flow of the Connecticut River at the State line which is shown by Exhibit D-2 to have been 3000 cubic feet per second; (538-543) that Dr. Rudolfs read into the record his daily determination of dissolved oxygen in parts per million and of water temperature at sampling stations on the Connecticut River at the Massachusetts-Connecticut State line (his Station A), at a point above Hartford (his Station F), and at a point below Hartford (his Station J), during the period September 1 to 11, inclusive, 1929, as follows:— (543a)

Station Location	A State Line		F Above Hartford		H Below Hartford	
Date	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
Sept. 1929	P.P.M.	°C	P.P.M.	°C	P.P.M.	°C
1	4.3	20.2			5.8	20.8
2	3.85	21.2			5.2	21.9
3	3.25	21.7			5.7	22.6
4	2.9	22.2			4.6	23.9
5	4.85	22.3	5.8	23.6	5.0	24.2
6	4.3	22.5			—	—
7	3.5	22.6			4.5	22.2
8	3.35	23.2			—	—
9	3.7	23.5			—	—
10	2.0	22.7			4.2	24.0
11	4.5	22.0			—	—

(544 et seq.) that a complete list of his sampling stations at the State line and below are as follows:—

Station A—Connecticut River at Massachusetts-Connecticut State line.

Station B—Connecticut River at Thompsonville bridge, (about 2½ miles below State line).

Station C—Connecticut River opposite lower end of the Northern Connecticut Power Company canal.

Station D—Connecticut River directly west from South Windsor and one-half mile below the mouth of the Farmington River.

Station E—Farmington River at highway bridge at Windsor.

Station F—Connecticut River 500 feet above N. Y., N. H. & H. R. R. bridge at north end of Hartford.

Station G—Hockanum River at mouth.

Station H—Connecticut River one mile below mouth of Hockanum River.

Station I—Connecticut River at Wethersfield.

Station J—Connecticut River at Rocky Hill.

Stations K-1 & K-2—Connecticut River at Middletown.

Station L—Sebethe (Mattabesset) River at highway bridge near mouth.

Station M—Connecticut River, one and one-half miles below Middletown.

Station N—Connecticut River at East Haddam bridge.

Station O—Connecticut River at Saybrook bridge.

Station P—Park River at mouth.

(547) that the condition in the Connecticut River as shown by the results of his tests in 1929 does not improve between Station A at the State line and Station B at Thompsonville, in fact is a little "poorer" at Station B, "but comparing the results at Station B with Station C, which is further down the stream, below the Enfield dam, the condition improved very

materially;" (547) that the results of studies which were made to determine a reason for the betterment of conditions on the river between the Massachusetts-Connecticut State line and the station just above Hartford known as Station F, which conditions improved very materially in 1929; that there is a dam of about six to seven feet high, and below that dam there is a stretch of about a mile or a mile and a half of ripples, over which the water at low tide goes continuously and is reaerated very vigorously.

(548) "Q. Assuming that you have a dam at Kings Island, of substantially the same height as the present dam, but you increase your pondage, will that have a tendency to either benefit the conditions or make them worse, so far as the chemical analysis of the water is concerned? A. Suppose that you put in (549) another dam there and back up the water to the level of the first dam, I would say you might cut your reaeration and your results about in half.

Q. That is from the chemical and not from the bacteriological? A. I am not talking about the bacteriological.

MR. WARREN. It is just the other way with the chemical side as compared with the bacteriological side?

THE WITNESS. It would not help with the chemical.

MR. WARREN. You heard what Professor Winslow said?

THE WITNESS. Yes.

MR. WARREN. That the increase in the pondage would help from the bacteriological standpoint, and you say it would cut in half the present improvement in the oxygen?

THE WITNESS. If I had to give an opinion on the bacteriological side I would have to know first how long that ponding would be, before I could say anything about it. Suppose it is 30 days, I would say yes, it would

materially help bacteriological removal. If it is an hour, I do not see what difference it would make."

(550) That some 24 hour rests were made at the State line from the result of which it was determined at what hour the average sample would be obtained; that this process was repeated several times; that he wanted to check up and see how it held all summer with different flows; that most of the time they were made at 8 o'clock; (551) that in 1928 they sampled every hour and a half for seven days, night and day, and from that, constructed curves for every day and from that took the average condition for each particular day they were going to sample, so that the hours varied throughout the week between 8 and 12 in the morning; that those tests were made in June before starting the regular survey which has been reported here; (552) that the survey was made, beginning on June 16th and ending on June 26th; (553) that every day a sample was taken during the regular period in 1928; that (554) in 1929 between July 8th and July 27th another survey was made similar to those done for ten days the year before at hour and a half intervals for twenty-four periods on July 27th and 28th; that another sampling period of an hour and a half sampling was taken on August 13th and 14th and again on August 25th and 26th; that they found that the average conditions were near 8 o'clock in the morning; that outside of these special periods of sampling, one sample was taken each day——

Q. Will you agree that whatever oxygen the water did have after the sludge bed had exerted its influence on the water as it came down the stream, had been exerted when that particular water reached the State line and that, therefore, you know what kind of water Connecticut got at the State line on the day that you took your sample? A. The four specific days, yes, but not for the general period, because then we have to bring in that picture of accumulation.

Q. You took a sample every day? A. For a certain period of the year, yes, sir.

Q. And for that period the samples showed the kind of water that Connecticut got at the state boundary, no matter how big the sludge bed was? A. Yes.

Q. Whether it would have continued to get that kind of water or not, of course you cannot tell after you stopped taking your samples? A. Yes, sir.

Q. But if samples had been taken continuously from the time you stopped, then you would have gotten a picture for that larger period. A. More complete.

Q. And you could have determined more definitely and accurately what the evil effect of the sludge bed was; is that right? A. Yes.

(571) That his surveys indicated sludge beds as follows:—

Location	Area in sq. ft.	Average Depth in feet
Holyoke opposite Hegy works	90,000	0.33
Holyoke-Springfield line	103,000	1.65
Chicopee, below bridge	161,000	1.40
(572)		
Springfield North End Bridge	266,000	1.21
Springfield at railroad bridge	520,000	1.71
Springfield, Memorial Bridge	170,000	1.20
Springfield, Charles Miller and Sons—whatever that is	164,000	1.00
Springfield, Mill River	96,000	0.75
Springfield, South End Bridge	175,000	1.10

(573) That he heard what Dr. Winslow said about a five percent increase or decrease in the flow of the river; that he does not agree with him from the chemical standpoint; that any addition or any diversion would have an effect from from the chemical standpoint.

(575) "Q. For instance, suppose I take a sample —suppose the river is flowing 10,000 cubic feet per second, and suppose that 100 cubic feet per second is added to the flow and you took a sample before that hundred cubic feet per second was added, and another sample after it was added. Do you think that your analysis of the two samples would in any way indicate the addition of the 100 cubic feet per second to the flow? A. Ten thousand cubic feet per second? That is a large quantity of water.

Q. But you would get a good, fair sample of it from mid-depth, couldn't you? A. Fair.

Q. The way you take it? A. Fair, as we try to do.

Q. All right, now let's add 100 cubic feet per second to the flow of the river, and you take the sample at the same place in the same way, after the 100 cubic feet are added, cubic feet per second are added?

MR. HOLDEN. I suppose the witness is to assume that the 100 cubic feet that is added is the same kind of water which is already flowing through, is it?

MR. AVERILL. No.

MR. HOLDEN. Or is it?

MR. WARREN. It is nice, pure water.

MR. AVERILL. Better water?

MR. WARREN. Better water.

A. It would be very difficult for me to say offhand without having some figures or calculations, whether you would be able to figure that. I know that that 100 cubic feet per second of water has a definite amount of oxygen, and if I add that definite amount of oxygen I know that I add so many pounds which can take care of the sewage of such a population, which is about, say, 35,000 people. If I added water I know I can take care of 35,000 people more. If I substracted, I know that I can take less by that number of people. Now if I have a flow in the river at a certain time of the year, when I need all of the water for dilution, and I took that out, then I know that I can't treat the sewage of so many people less, 35,000 people. On the other hand, if I need that water and I get it, that with any addition, my conditions in the river must necessarily change, in proportion to the amount of water I get,—betterment, so I can treat the sewage of more people with every cubic foot of water you give me, you can treat more people's sewage, with every quantity you take out you can treat less. And that is a clear-cut picture.

Q. Yes, but what I want to know is whether you can tell by your chemical analysis how much water has been taken out or how much has been added? Of course I know you can, at a certain point, but what is that point at which you can determine that? A. I don't see the question clear.

Q. Well, let me try to make it clear. Assume, again 10,000 cubic feet per second flowing in a river, say the Connecticut River, and the 100 cubic foot per second is added, and you take the sample before and after the addition of the 100 cubic feet per second, the 100 cubic feet per second being good water. A. With 10,000 cubic feet, per second I think, your chemical methods would be within the experimental error.

Q. So that you cannot tell, or could tell? A. Not with certainty.

Q. You couldn't tell? A. But that doesn't take anything of the effect that you take out water or add water.

Q. Oh, no, of course, I understand that. If you add water there is more water, and if you subtract water there is less water. A. Which means treatment or no treatment.

Q. Yes, but what I want to know is if you can tell in your analysis? Now there must be some point where your analysis would enable you to tell, suppose it was 500 cubic feet per second? A. I think you would be able to tell.

Q. You would be able to tell that? A. Yes, Sir.

Q. Either way? A. Yes, sir.

Q. Added or subtracted? A. Yes, sir.

Q. Well, how about three? A. I think that is about the border line.

Q. That is about the border line? And less than three you probably could not determine it? A. Not with certainty, sir.

(578) referring to figures of dissolved oxygen in the Connecticut River near the mouth of the Hockanum River previously testified to by him:—

Q. These figures indicate that fish could live in the water at Hartford, couldn't they? A. I think they are just above the border line, yes.

Q. Yes and those figures were the dry weather figures? A. Yes, sir."

(581) That assuming that there was an average flow for a summer season of 5,050 cubic feet per second, and 100 cubic feet per second of pure water was added or subtracted, he thinks it could be determined in the result; that the condition of the water at the State line on any particular day is its condition after it has passed over any sludge beds within the State of Massachusetts, on that day; that if a sample of water is taken the effect of the sludge beds in Massachusetts on that particular water has been exerted; that if the velocity of the stream is not sufficient, then the sludge beds will grow; (582) that they are more apt to grow at a time of year when the flow is less; that they are most apt to disintegrate to some extent if the velocity of the water increases materially; that that would be probably in the spring, when there is high water.

ROBERT SPURR WESTON, an expert witness for Massachusetts, testified (729) that he first came into the case in July 1928, and took over the direction of certain studies; that these studies consisted of making as complete chemical and biological and hydraulic records as time and circumstances would permit of the Connecticut River and tributaries, particularly the Chicopee with its sub-tributaries, the Ware and Swift and Quaboag Rivers; that the hydraulic work was done under the direction of Mr. Sears of the Metropolitan District Water Supply Commission and the chemical and bacteriological work was done under the direction of Walter H. Junkins in a laboratory established in Springfield; that (730) the laboratory began making analyses before the first of October 1928; that a number of stations were established, numbered and located as follows:—on the Connecticut River, station No. 15 at the northernmost bridge in Northfield, station No. 6 below Holyoke and above the northernmost sewer discharge from the city of Chicopee into the Connecticut River, station No. 5 at the mouth of the Chicopee River, station No. 3 at the mouth of the Westfield River, station No. 1 at the state line at

Enfield, and station No. 20 at the ferry at Rocky Hill which is approximately 8 miles below the city of Hartford (731) that on the Chicopee River there were two stations, one at Bircham Bend, just between Chicopee at Three Rivers, and on the Swift, Ware and Quaboag Rivers near their mouths, and additional special stations on the Swift River; that in addition to the stations enumerated above a number of special stations were established; (731, 732) that several long term experiments were made at Dividend Bend, which is on the Connecticut River between Rocky Hill and Middletown for the purpose of studying the effect of the oscillating tidal prism; (733) that the analytical work was limited to necessities; that amount of dissolved oxygen and carbon dioxide present in the water was determined in the field, biochemical oxygen demand was determined in the laboratory as well as most of the usual chemical determination and bacteriological samples; (734) that most attention was given to samples collected at the stations on the Connecticut River at Holyoke, the state line, and Rocky Hill; that in order to avoid the errors due to the exclusion of Sunday as a sampling day, a five day sampling schedule was laid out and this schedule was moved along two days each week; (735) that greatest care was taken to check the work and insure the precision of the method that in addition to the regular determinations enumerated above, special studies were made of the sources of industrial pollution on the Chicopee, Ware, and Swift rivers and in one instance on the Quaboag; that these studies were made to obtain an idea of the contributions of pollution by the various manufacturing establishments above the mouth of the Chicopee River; that they usually consisted of twenty-four hour tests being made mostly during the winters of 1928 and 1929, and in several cases were repeated; that in general these tests consisted of as accurate a determination as practicable of the flow of the river above and below each plant for a period of twenty-four hours and the collection of samples above and below the same plant for the determination of the chemical and bio-chemical character of the industrial waste; that in this way it was possible to

determine the specific amount of pollution contributed on the day of the test expressed in pounds of constituents discharged by the plant being tested; (736) that early in the work Dr. Tierault of the United States Public Health Service who has made special studies of the methods of determining the biochemical oxygen demand and dissolved oxygen of streams, was employed for a few days to check up all our methods in this regard to see whether or not they were in accordance with the best work in the best laboratories; that the 5-day schedule referred to above was adhered to in 1928 up to the close of navigation which was the 17th of December; that after that a boat could not be used, so the winter season catch samples were taken at the stations either from the shore or in some instances from the center of the river through the ice; that in lieu of the sampling at the state line, samples were taken from the canal which leads from the Enfield Dam through Windsor Locks; that the sample schedule in the winter was reduced since the flows were high (737) and the difficulty was much greater; that samples were taken from the canal as described above once or twice a week; (738) that the schedule started with some determinations about the 17th of September and all determinations were made before the first of October, and continued until the river froze; that they were resumed after the ice moved out of the river and carried on until November 1929; (739) that the practice in taking the samples at the state line was to start in the morning with the boat from Springfield and go to the state line, arriving there between 8 and 9 o'clock in the morning; that a sample would be taken at mid-depth near the easterly shore, midway between the easterly shore and the center, at the center, and at the westerly shore; that this operation would be repeated in two hours, usually after a third two hours, and sometimes after a fourth two hours, so that not only was the cross section of the river covered at three places but also three different times in the day; that this was done in order to avoid any errors in sampling due to catching just one sample at one place at one time; that the amount of dissolved oxygen and carbon dioxide gases

in each portion collected was determined on the boat, then the three or four portions, as might be the case, collected from the easterly shore were mixed, three portions from the center were mixed and the three portions from the westerly shore mixed to form (740) 3 chemical samples which were brought to the laboratory for analysis so that for each sample there was made 6, 9, or 12 dissolved oxygen determinations depending upon the number of portions making up the chemical samples, and three complete chemical analyses; (1387) that over four thousand samples were taken out of the Connecticut River, most of the time at ten stations and a few samples taken at five other stations; that the period covered was from September 1928 until the present time, and while the river is still being sampled, the period taken into account in the statistics used in the preparation of this case was a 14-months period beginning with October 1928, (1388) a period of 14 consecutive months; that this was a good period for observation as the stream flow conditions were favorable for determining what might be called, the average condition—the fairly full flood stage condition, and the dry weather condition; that the period, August, September and October, 1929, was one when the flow in the stream was 0.53 of a second foot per square mile and in a series of 17 years, one would find in that period about one year out of five when three drier months would occur, and four years out of five when three wetter months would occur; that is to say, the three driest months in the year would be wetter than the three months of observation; namely, August, September and October, 1929; that the average flow for the whole period of 14 months was just a little less than the mean flow of the river, which is 1.77 of a second foot per square mile; that conditions were normal during October, November and December 1928, followed by a transition month of January, then three wet months again followed by a transition stage, followed in turn by three dry months, and then the month of November when conditions were wetter than they were in October (1389); that the period of observation included three months when the river was way below normal flow and a

shorter period when the flow was considerably below the average for the three months of the examination of the river, and during such time as it was very low, the principal effect was that it showed ample dissolved oxygen in the river to take care of the pollution which now exists, and some margin for future pollution; that pollution becomes more marked as the supply of water decreases, and the pollution decreases as the supply of water increases; that pollution is of importance and enters into the sanitary standpoint only so far as bathing, drinking, nuisance from odors and its effect on fish life are concerned; (1390) that dissolved oxygen is the oxygen which water will dissolve from the air by exposure of the surface of the water to the air; that it is the amount of oxygen available in water which can attack, and break down sewage and industrial waste; that bio-chemical oxygen demand is the requirement of oxygen that sewage and industrial waste present in the water make, and may be as the measure of pollution in terms of the amount of oxygen required to oxidize pollution; that oxygen balance is the amount of dissolved oxygen left after the bio-chemical oxygen demand is made and satisfied; that parts per million means a part of anything in a million parts of water, and pounds per million means the pounds of oxygen to a million pounds of water; (1391) that population capacity means the capacity which a stream has of oxidizing the pollution produced by population in terms of the number of population, for example, the population capacity of 1,000 means the ability of the stream to care for the sewage produced by 1,000 people or the industrial waste equivalent to 1,000 people and (1392) includes not only the sewage of humans but also the industrial population equivalent; that the result of the analysis of water with reference to dissolved oxygen shows that except on a few occasions (a few individual samples) the water was more than 50% saturation, with always enough oxygen at all of the stations, including the state line, to take care of the pollution of the river at that point, and leave considerable population capacity to spare; that this was true of all stations on the river including the low stages, basing the statement on

monthly averages obtained during a series of 14 months; that the condition of the water with reference to the dissolved oxygen is at the state line, the net result of pollution and natural purification after all elements, such as sludge beds, sewage and industrial waste have exerted their force; that were it not for sludge beds, sewage and industrial waste, (1393) the amount of dissolved oxygen at the state line would be considerably higher; that at no time during the examination was the supply of dissolved oxygen insufficient to meet the requirements; that judging from Dr. Winslow's testimony of his observation of the stream, there is an increase in dissolved oxygen between the state line and a point above Hartford; that he had made no observations at Hartford on this point; that between the state line and Rocky Hill, which is the Massachusetts station next below Hartford, there is an increase in the supply of oxygen; that that station was at a point considerably below which the sewage of Hartford empties; that the supply of dissolved oxygen is greater at that point even though the Hartford sewage has been turned into the river, because of the re-aeration of the stream between the two points, or the stretch between the state line and Rocky Hill; that just below the state line the river runs over a considerable rapid so that there is (1394) a long stretch where the contact between the water and the air is considerable, and the flow is more moderate than in the upper river affording ample opportunity for re-aeration, so that by the time the water reaches Rocky Hill the capacity for caring for sewage is increased rather than decreased notwithstanding the addition of sewage from Hartford and other towns in Connecticut; that (1395) considerable bio-chemical oxygen demand arises just below Hartford as a result of the sewage, but in spite of this, the dissolved oxygen at that point is greater than at the state line; that Rocky Hill is about 11 miles below Hartford; that he knows and understands that the average diversion of the water of the Connecticut River by the Ware-Swift enterprise under the War Department restrictions would be (1396) about 2%, and assuming that the diversion were made during the fourteen

months of sampling there would have been a variation from 1/10th to 2 or 3/10ths parts per million either way, in dissolved oxygen or practically insignificant; that translated into percentage, when the water contains 10 parts per million, it might be plus or minus 1% as an average; that the effect of the proposed release of water from the Swift River upon the Connecticut River as to the amount of dissolved oxygen, would be so very slight that it could not be detected at such time as the water is being diverted from the Connecticut River, and there will not be any appreciable effect on the supply of dissolved oxygen; that regarding Professor Winslow's testimony, that it would not be possible to detect a diversion within 5% (1397), the witness thinks that it would not be practicable to do it but if there were available an unlimited research force, and the stream could be controlled, that figure (the 5%) might be reduced somewhat; that he does not believe that the addition or subtraction of 5% of the flow of the river would make any material difference; that he would not like to increase the diversion too much above 5%, certainly anything below 5% would be a safe diversion; that the witness does not believe that a diversion of 2% could be detected, and would have no material effect on the river, no advantage or disadvantage; (1398) that sludge beds which form near the mouth of all sewage outlets and during periods of low velocity, and which are washed away during floods, have the effect during periods of low flow of removing from the river certain materials which would ordinarily be carried down the river and rob the water of its oxygen in the lower portions of the stream, reserving the use of oxygen until such times of high water when the sludge can be carried down stream and use up the oxygen without any harm; that in general a formation of sludge beds in pools like that above the Enfield Dam in dry weather, is an advantage to the stream because it delays the presentation of pollution down in Connecticut where if present it would rob the Connecticut portion of the river of its oxygen more rapidly than if the sludge had not settled out in the river; that in considering his answer that the diver-

sion under the two Acts as modified by the War Department, he considered the fact that there were sludge beds in the river; that the table showing the effect of diversion on dissolved oxygen at (1399) the state line for the months of October, November and December, 1928 and for the months of January to November inclusive, of 1929, (Ex. D-8) shows that in (1400) the month of October 1928 there would be 9.1 parts per million before diversion and 9.0 after diversion; in other words, a reduction as the result of the Massachusetts diversion of 1/10th parts per million; that in November 1928 there would have been an increase in the dissolved oxygen because the dissolved oxygen in the water released from the Swift-Ware Rivers was more concentrated than in the Connecticut River water; that December shows a decrease of 1/10th and January and February 1929 an increase of 1/10th; that the conclusion from this table is that the effects of the diversion are away inside of our powers to detect oxygen in water; that (1401) it is possible to detect changes in dissolved oxygen of 3/10th of a part per million plus or minus; that in the future, if the population above the Connecticut line doubles, the bio-chemical oxygen demand will also double, but the oxygen balance will decrease by not quite 50%; that the reason for this is, that the more the oxygen balance decreases the more the factor of re-aeration comes into effect; (1402) that if the water was saturated with oxygen and carrying a certain amount of pollution and the pollution was increased by one-half, the effect on the stream would be greater than if the water was already polluted and the pollution was increased by one-half, just as a sponge that is partially dry absorbs more water than one full of water, so the river partially depleted in oxygen absorbs oxygen from the air more rapidly; that this is the reason that there is not the same proportional effect of pollution if an already polluted river is polluted, than if a river in the state of nature were polluted; that in other words, the more polluted a stream is, the faster it will absorb new dissolved oxygen by aeration, the more rapidly it will recover; that "nature comes to the rescue more

potently when a stream is depleted"; (1403) that the additional absorption of dissolved oxygen in the Connecticut River keeps pace pretty well with the increased population, and below the state line more than keeps pace; (1403) that the increase of population can be offset as to its sewage and industrial waste by treating the sewage; that from his experience that is a way of utilizing the stream; that in his opinion, with reference to the probable effect of the increased population above the Connecticut-Massachusetts state line, on the pollution of the Connecticut River in the future, if pollution be increased rapidly and be unrestricted, the river will suffer, but it is possible to keep the river not only in as good condition as it is now but to improve it considerably by sewage treatment, and by certain types of sewage purification, that is, the best types; that it would be possible to give it more carrying capacity in the summer than it now has, by as much as 100 percent; (1404, 1405) that referring again to the table Exhibit D-8, in calculating the effect of the addition to or diversion from the Connecticut River the quality of the water in the Swift and Ware Rivers used, was on the basis of their existing condition, and that the fact that as this water goes down the Chicopee River, it will become heavily polluted, was taken into consideration; that (1405) there is another effect; that the Chicopee River consists of a series of ponds and ripples, and the re-aeration effect in the Chicopee is considerably more than in the Connecticut on that account; (1406) that the witness has read over the testimony of Dr. Winslow and Dr. Rudolfs, and has obtained considerably higher results than did Dr. Rudolfs at the state line; that his results are based on the monthly averages, but even for the periods for which they got results like the period from November 1st to 11th, his dissolved oxygen results were considerably higher; but that in general he finds some agreement (1407) that he took more observations than they (the Conn. Engineers) did at the same point; that he took either 6, 9, or 12, observations a day but did not make any 24 hour tests; that he agrees with Dr. Winslow that the river is in good condition at the

present time but he does not agree with Dr. Winslow that the river is in a condition to be "tipped over" by a small depletion of oxygen; that the few occasions when the dissolved oxygen was less than 50% were not at the state line; that he cannot say that sludge beds are a benefit but that if sewage is being discharged into a slow stream, it is a benefit to have the sludge kept near the sewer outlet and not be carried to the lower stream; (1408) that while all the sludge beds have an oxygen demand, they use up the oxygen more slowly when they are on the bottom of the stream than if they are suspended in the water; that the actual condition is that there are sludge beds in the stream; that they have an oxygen demand, which has to be supplied from the water; that anything that goes out of the sewer has to be supplied with oxygen from the water to be purified; that when the stream flow is higher some of the sludge beds go down stream where the water is more able to take care of them; that the sludge beds in depositing on the bottom in the summer months and staying there, are possibly of little benefit in retarding the possible amount of demand which might be created lower down; that the fact that some of the sludge beds are taken away by the higher flow, does not hurt, because at that time there is plenty of water to supply the demand; (1410) that referring to Exhibit D-9, the figure 9930 in the first column (1411) represents the flow of the Connecticut River in Connecticut at the Enfield Dam in cubic feet per second during the month of October 1928; and that next figure on the same line, 6418 represents the same quantity expressed in million gallons a day, and that the figure in the third column 1.02 represents the same discharge expressed in terms of cubic feet per second per square mile of catchment area above the dam, and in the 4th, the same discharge is expressed in terms of million gallons daily per square mile of catchment area; that (1412) the mean annual discharge at the Enfield Dam is 17,000 cubic feet per second (the term "second feet" is synonymous with cubic feet per second); that the purpose of this table is to show the hydraulic conditions under which

the observations, which the witness has been testifying to, were taken; (1414) that the lowest amount of dissolved oxygen found by the witness in the Connecticut River was at station No. 1 (at the state line) on September 8th; that at this time the dissolved oxygen had a value of 3.75 parts per million which is equivalent to 44% saturation; that the average for the period of September 5th to September 13th inclusive, was 4.70 parts per million which is 53% saturation; that the Swift River at the present time averages 92% saturation; that the Ware River at the point where the taking is to be made, he would expect to have about the same per cent saturation; that on September 8th referred to above, water would have been released from the Swift River Reservoir and no water would have been diverted from the Ware River; that the figures (1415) on Ex. D-9 in each of the columns represent monthly averages.

EARL B. PHELPS, an expert witness for Massachusetts, testified (1482) that the population capacity of the stream is its oxygen balance expressed in terms of population; that Dr. Rudolfs has told how it is possible to evaluate the sewage and other wastes of a given population in terms of oxygen and he has made use of that principle to express his industrial wastes in terms of equivalent population; that it is found convenient to carry this process one stage further and to express the oxygen equivalents determined by analysis of the waters likewise in terms of population; that since populations primarily are being dealt with this gives a unit for comparison which is much more intelligible than the ordinary analytical expressions, that population capacity of the stream, therefore, is its ability to provide for the wastes of a given population during the time of passage to saltwater and under the temperature conditions existing at that stream; that it represents in brief the reserve capacity of the stream to care for additional pollution over and above that which it now contains and to carry that pollution to the sea without the production of a resulting nuisance, (1483)

that when the Dr. Winslow says the ability of a stream to take care of sewage and industrial wastes he means the ability of the net balance of dissolved oxygen over and above everything that is in the stream or that has happened to the stream by way of pollution in the past; that the net balance from time of sampling to the sea is the basis for population capacity; (1484) that the net balance of which he speaks is what has been referred to in the case as oxygen balance; referring to Exhibit D-14,—

Q. "Supposing we start with October, 1928, and run that right across as typical of the other months. The first figure under column 1 is 3,887,000. What does that mean? A. That is the population capacity, as I have defined it, of the Connecticut River at the state line.

Q. During the month of October, 1928? A. During the month of October; yes, sir.

Q. The next column is 59,000 with a minus sign in front of it. What is that? A. That is the population capacity of the water of the Swift River which would have been diverted during the month of October, 1928, under the Massachusetts legislation and the War Department restrictions.

Q. And the minus sign means that it would reduce the population capacity of the Connecticut River at the state line by that many thousand people; is that right? A. Yes."

(1485) Q. "That again is for the month of October, 1928? A. Yes.

Q. The third column is simply a subtraction of the second from the first, isn't it? A. Yes.

Q. So that after the Swift and Ware River diversions, such as they may be, during that month, the remaining population capacity at the state line is the figure, 3,828,000? A. Yes.

Q. What is your fourth column, "Percent change?" A. That is merely the value of column 2 divided by column 1. It represents the diversion in terms of population capacity and as a percentage of the total population capacity of the river at the state line.

Q. So that the population capacity at the state line is reduced by the diversions, 1.5 percent during that month? A. Yes, sir.

Q. Your last column, again for October, 1928, 1.3; what does that mean? A. That is a similar term that refers to the actual volumetric flow of water. That is, it states that 1.3 percent of the total volume of water passing the state line during that month would have been diverted.

Q. Skipping down to August, 1929, your first column is 368,000? A. Yes.

Q. That, of course, means that at the state line during the month the population capacity of the river was that many people? A. Yes.

Q. Your next column is the first one that has a plus sign before it. It says plus 5,000. What does that mean? A. That signifies that under the War Department regulations there would have been a release of water from the Swift during that month, and the excess of release over the normal flow of the river for that month is equivalent to 5,000 population. (1486)

Q. That, of course, adds that number to your third column? A. Yes.

Q. And your fourth column shows an increase in percentage of population capacity? A. Yes.

Q. And the fifth column shows that instead of being a diversion there was an addition of nine-tenths of one percent; is that right? A. Yes;"

That the table, Exhibit D-15, summarizes the results of analytical determinations of the various oxygen quantities involved at the sampling stations at the state line and at Rocky Hill, which is about 10 miles below Hartford; that the first column shows the population capacity of the Connecticut River at the state line, month by month; that the second column shows the population capacity of the Connecticut River at Rocky Hill during each of the same months; (1490) that the fact that the population capacity at Rocky Hill, as shown on Exhibit D-15, is so much greater than the population capacity at the state line is due to several factors, chiefly to re-aeration; that the population capacity is based upon oxygen balance, and the oxygen balance, in turn, is determined by two factors, one, which corresponds to the cash on hand in a bank statement, is the asset value, the oxygen present; and the other,

which corresponds to notes not yet due in the statement, is the demand; that the oxygen balance is the balance of the statement, and as re-aeration, which is income increases the cash reserves, the population capacity is increased in proportion; (1491) that there are some other considerations that enter that; that the somewhat nearer distance to salt water makes the value of a pound of oxygen somewhat greater, that is, a pound of oxygen from Rocky Hill must needs carry the sewage for less time, a shorter time, than a pound of oxygen from the State line, so that pound for pound the resources at Rocky Hill are somewhat more valuable; that, completing the financial parallel, it is as if a merger with a larger solvent concern were in prospect at a certain date; that notes extending beyond that date would not be presented therefore and conditions in insolvency might be prevented by the merger taking place before the notes came due; that this demand is a continuing thing and it is exerted over a lapse of time and, briefly, then if the water reaches the ocean—the salt ocean—before all the notes are presented, there is no further danger of oxygen insolvency; that, to put it perhaps in its simplest terms, the two columns in Table 6 show the proportion of improvement in the water between the state line and Rocky Hill; (1492) that the table simply shows that the population capacity at Rocky Hill below the point where the Hartford sewage is discharged into the river is greater than it was at the state line, and the figures show how much greater; that Exhibit D-14 indicates an improvement so far as it goes in the population capacity of the Connecticut River at the State line during the month of August, September and October of 1929, due to the release of water from the Swift River; (1493) that it is almost nothing as many of these figures are; but that the indication from the computations is an improvement in the river;

> "Q. Now, Professor Phelps, I am going to read to you certain testimony given by Dr. Winslow. It seems to me that this is the shortest and simplest way to summarize your testimony, if you will follow this testimony that I

will read from the record. On page 514 of the record the following questions and answers were asked on direct examination of Dr. Winslow:

'Q. Now, you are acquainted in a general way with the Massachusetts legislation as to the abstraction of water authorized under that legislation of Massachusetts? A. In a general way, yes, sir.

'Q. You are acquainted with the restrictions imposed by the War Department? A. Yes, sir.

'Q. How much effect would the restrictions imposed by the War Department have upon the Connecticut River at the State line, assuming they are complied with? A. I don't think that the change would be sufficient one way or the other during the summer months to be detected by any methods at our disposal, either way.'

"Do you agree with that conclusion so far. A. Yes. Q. "Reading):

'Q. It doesn't make any difference whether it is the Massachusetts legislation or the restrictions of the War Department? A. Just look at it from a broad—let me try to look at it not as an expert, but from a broad common sense standpoint at the beginning. Say you are putting in or taking out something well under 5 per cent. Now, then, none of these methods we are using on the river would check on samples taken half an hour apart within 5 per cent. In other words, I cannot conceive that the effect of these differences and the change in the condition at the State line could be detected by any means we now pursue.

'Mr. Warren. What do you mean?

'The Witness. I mean if you take out 5 per cent of the water in the Connecticut River or 5 per cent of the oxygen, or if you put it in, put in 5 per cent more or take it out of that now reaching the State line, if you could take the river just above the State line and had a magnet and could pick out 5 per cent of the oxygen or put in 5 per cent more of oxygen, nobody would be able to tell the difference. If the experts on both sides of this case were there before and

afterwards, I doubt if they would be able to obtain results that would show a difference."

(1494) "Do you agree with that? A. Yes.

"Q. This is a continuation of the same answer:

'If you take out 10 percent, I am inclined to think you could probably find a damage or a benefit, depending on whether you are putting it in or taking it out. Then if you got 20 per cent, I am rather sure you would have a rather definite and appreciable and serious result if you diverted out of this flow.'

(1495) "Do you agree to that? A. Well, I am not sure about the serious result. I haven't investigated that. But, in general, I agree with Professor Winslow, that that might be about the line that would be noticeable."

"Q. Now, skipping somewhat here, because it is simply apparent an example, he then goes on and says this:

'We can say that every quart we take out makes it worse or every quart we put in makes it better, but within the limits we can use in analyzing you would have to have 10 per cent change, let us say, one way or the other before you could get anything that would really be significant.

Q. So that so far as the actual condition of the water is concerned it isn't going to be materially affected one way or the other? A. I don't think so.

Q. It can't be any better and you don't think it would be any worse? A. I don't think either diversion under the War Department ruling or diversion under the Massachusetts statute, as I understand it, would make any detectable difference in the water at the State line.

Q. At present? A. At present.'

"Do you agree with that statement that I just read? A. Yes, yes, I do.

"Q. Now, on the following page appears this question?

'So that if the compensation from the diversion of the Ware and Swift Rivers amounted to 10 per cent in your oxygen in spite of the amount which is authorized to be released under the War Department's restric-

tion, you would have a substantial benefit instead of a situation which does not change the present situation? A. (1496) I think anything that added 10 per cent to the pure water in the Connecticut River would benefit it appreciably.'

"Do you agree to that? A. I wouldn't think it was a very material benefit, no, in view of these showings. That is just about the limit of analytical determination. I think his general conclusion here is safe.

(1497) "Q. Going on to page 520, Mr. Warren, on cross-examination, asked these questions (reading):

'Q. Supposing that the flow of the Swift River during that period was 1.3 per cent of the Connecticut's flow at the state line, would that amount fall within the quantities which you described as neglible and non-detectable? A. I think it would, sir, yes.'

"Do you agree with that? A. Yes, fully.

"Q. (Reading):

'Q. And, as I understood you, neither you nor the experts on our side would be able to determine with any satisfaction to themselves or to yourself, what the effect of that was, that addition or subtraction? A. Assuming it to be 1.3 percent of the total flow of the river?

'Q. Of the total flow of the river. A. Yes; I think that is true.'

"You have indicated that you agreed with that? A. Yes.

"Q. (Reading):

'Q. As I understood you, that would be true probably up to a contribution or a diversion of about 5 percent? A. I should say somewhere around there, yes.

'Q. And after 5 percent it would become detectable and at 10 percent I think you stated it would be detectable? A. Yes.'

"That as to those percentages he cannot agree with Professor Winslow about the matter of detecting

the changes; (1498) that he doubts whether even a 20 percent subtraction would make a serious condition under the present existing conditions, because of the great improvement of the river shown by my figures, between the state line and the Rocky Hill Station.

That as to the five percent conclusion of Professor Winslow he is heartily in accord and thinks he is quite right; that five percent is below the limits of our analytical work; carefully analyzed all his data as to their probable accuracy, including errors of sampling which, of course, are large; that one is dealing with a chance sample here, taking a bottle out of a great river; that he had to allow for errors of sampling, the error of time of sampling, the hour of taking the sample, and the errors of location of samples, both as across the river and up and down, and all those things, plus his laboratory accuracy, which led him to believe that about 10 percent is about the degree of accuracy of the work on these monthly statements; that carried through a year, perhaps a little better than 10 percent would be possible; that anything beneath 10 per cent is certainly not significant; that one is limited to the accuracy of our measurements.

"Q. I will read you a few more questions and answers, and I think we will then probably conclude (reading):

'Q. Would you say that that same conclusion was true as regards the public health? A. Well, yes, I should because you would have to have an enormous change in quality on the one hand and an enormous improvement to make the river safe for bathing. (1499) You would have to have a very large change for the worse to make it impossible to purify it by storage, chlorination or filtration. I should say, then, that a change of five percent either way was not of practical moment.'

"You agree with that? Yes, quite fully.

(1500) 'Q. Either as regards the purity of the water or the effect of the water with respect to public health? A. Yes, sir.'

"And that meets your approval? A. Yes.

"Now, follow this, Professor Phelps, a question by Mr. Warren on page 253:

'If there would be any determinable difference, how much difference do you think there would be in the cost of purifying the Connecticut River at Hartford, in the way you have suggested, by storage, filtration and chlorination, before and after this Ware and Swift River diversion? A. I have tried to indicate that the difference due to the abstraction of one per cent or two per cent of water is so slight that it cannot be measured in any concrete way. It is a purely theoretical damage or advantage when we are within those limits.

'Q. For any purpose? A. For any purpose that I know of we cannot determine within one or two per cent.

'Mr. Averill. You are speaking now of public health?

'The Witness. Yes, particularly of the cost of building a purification plant.

'Q. You have already said it did not make any technical difference in regard to public health? A. Yes.'

"Now, you agree to that? A. Yes, I do, quite fully.

"Q. Then Dr. Winslow went on and said that with reference to navigation and states that he was not competent to state. (1501) Now, assuming, Professor Phelps, that the population of Massachusetts above the State line grows in the next few years or in the future, what effect would that have on the population capacity of the Connecticut River at the State line? A. It will reduce the population capacity almost exactly in accordance with the amount of growth.

"Q. Now, is that same thing true as to the effect of an increase of population at a point above Hartford? A. Yes.

"Q. So that as the population doubles, for example, is it true in your opinion that the population capacity will be cut in half? A. No.

"Q. The same proportion. A. No, that is not the way it works.

"Q. How does it work? A. If we add 100,000 population, we subtract 100,000 from the population capacity. We have a population in the Springfield region of something like 350,000. Now we have a population capacity there in October of nearly 4 million. Now, if the population grows to 450,000 we would merely subtract 100,000 from that 4 million.

"Q. So that it simply lessens the population capacity by the number of people. A. Yes, exactly.

"Q. Representing the increase in population. A. That is at the nearby points. Now exactly 100,000 at Springfield would reduce the population capacity below Hartford by even less than 100,000.

"Q. And why is that? A. That is because with the greater draft upon the stream the force of re-aeration is more active. As the oxygen tends to be depleted, it is as if a vacuum were produced in the river, and Nature, abhorring a vacuum, attempts to fill it up. (1502) There is an oxygen pressure in the air alway pressing into the water, and as the pressure in the water is released the oxygenation is faster. So that the detriment, the lowering of oxygen in the stream never keeps pace with the increased demands. It always lags.

"Q. Have you figured out in any way a rough percentage as to the amount of decrease in population capacity, as compared to an increase in population above the State line? A. I was interested in Dr. Rudolf's estimate of future conditions, in which he thought that the population, including industrial wastes, might be doubled by a certain year. It is immaterial, of course, what year they may occur in. That is, that is out of the province of a chemist. But you can compute the effect of a double population. And if I may modify your question, I would assume that double population all the way down including the Connecticut population as well as the Massachusetts, and I find that the effect of doubling the population on the whole river above Rocky Hill would result in a 32 per cent change in the capacity at Rocky Hill. That is a 32 per cent decrease would follow a doubled population.

"Q. That is a 100 per cent increase in population? A. Yes, would result in a 32 per cent decrease in the actual oxygen present at Rocky Hill. That is the measure of nuisance.

"Q. And the reason for that is, as the river or as water becomes more saturated with sewage and wastes, that it much more rapidly absorbs oxygen. A. Yes. That is it, exactly."

(1503-1507) that figures of yearly averages on exhibit D-14 have no significance nor application; that the figures shown in the several months are monthly averages.

(1508) "Q. In order to clean this up, take your first month, October, 1928. To what extent exactly does the average day during that month come into the picture in making your computation? A. During any one month when the temperature and flow conditions are not varying greatly, it is proper to take all the things—figures that you have for the month—and average them up for the purpose of presenting a summary statement. It would not only be very cumbersome to put in the daily figures, but they wouldn't be so accurate. Our figures gain in accuracy as the average numbers of the determination. Any single determination during that month would not be as fair a representation of the month as this monthly average is.

"Q. And that average for October is just for that one month, is it not? A. Yes, that is the summary of all analytical data on the stream flow that we have for that month averaged together, and it shows better than any one figure for that month. We cannot use that for the whole year. It would not be fair to take this last average column for the whole conditions for the year, except with due consideration of what it means. It does represent the conditions for the whole year, but it cannot be taken, however, and said to represent the conditions for any one month. A month is short enough time so that averaged it is a fairly accurate story? A. Yes.

"Q. That is the answer, isn't it? A. Yes, I think perhaps if we wanted a statement of the yearly conditions the total line is better than the average line, although they are both of the same nature.

"Mr. Callahan. I think that is all. (1509)

"Mr. Holden. I want to ask him a question.

"Q. (By Mr. Holden) Did your estimate of ten per cent on the subject of accuracy—you recall that? A. Yes, yes.

"Q. Did your estimate of ten per cent on the subject of accuracy refer to one sample or to an average number of samples? A. This referred to monthly averages. We were taking something like twenty samples or twenty-five samples in the month and each sample—what we call a sample—would contain six actual bottles taken at three points on the river and at two different hours. Sometimes nine samples, nine bottles, would make up a sample. It is more than a simple dipping of one bottle into the river. Sometimes we take at three stations across the river, east, west and center, and for the most part at important stations that were taken over three hours.

"Q. But the point is you claim to be within ten per cent of accurate on an average number of samples? A. For the month, yes.

"Mr. Holden. I think that is all.

"Mr. Callahan. That is all. No further questions."

GEORGE W. FULLER, an expert witness called by Massachusetts, testified as follows: (2159)

Q. Mr. Fuller, did you hear the Winslow and Phelps testimony about the effect of diversion from the Ware and Swift upon pollution of the Connecticut River, or read them. A. Well, I heard Professor Phelps and I read Professor Winslow's testimony.

Q. And do you agree with their testimony? A. Yes, in so far as the proposed diversion will not effect any measurable influence on the quality of the water of the Connecticut River at the State line, and it is also my view that Professor Winslow made a very clear and very fair statement as to what the limitations are as to the methods of measurement of that pollution. I am very glad to affirm what Professor Winslow said in his summarizing statements and those matters which were read, I think, to Professor Phelps by Mr. Callahan.

GENERAL SANFORD H. WADHAMS, a witness for Connecticut, testified (980) that he is at present the Director of the Connecticut State Water Commission, and a member of the Commission; that it is one of the state agencies that came into existence in 1925 created to meet the demand that something be done to control the growing evil of pollution of the waterways of the State of Connecticut; that the Act was Chapter 143 of the Public Acts of 1925, entitled "An Act Concerning the Pollution of Water and creating a State Water Commission;" that he graduated in medicine from Yale University; that he was given the degrees of Bachelor of Philosophy, Doctor of Medicine and the honorary degree of Master of Arts; that he spent twenty-five years in the medical department of the army where he was more or less concerned with problems of sanitation; that he retired from the army following the World War with the rank of Colonel and was promoted to the rank of Brigadier-General on the reserve list; (982) that under the law the Commission is charged with the elimination, in so far as is possible, of the pollution of the waterways of the state; that the authority given the Commission is very broad; that in the Commission is vested the power to issue order to individuals, corporations or municipalities, to correct any pollution for which they may be responsible; that it places in a rather separate category new sources of pollution which come into existence after the passage of the Act, in fact, it absolutely prohibits anything of that kind; that one might think that that duplicates the functions of the State Department of Health, but that is not the case; that the State Department of Health has ample authority in law to take necessary action where the pollution of a waterway in any way menaces the public health; that the State Water Commission is concerned only with the economic aspects of the problem; that the reason for the Commission's existence is that already prior to the time it was created, industry was becoming hampered for the want of the necessary water of the proper quality and sufficient quantity; that in other words, the economic development of the State of Connecticut was approaching the

saturation point because, of course, it is a fact that industry is absolutely dependent upon the water necessary for its purposes, (983) that practically every industry requires water for the generation of power, or steam, or both, but more important for the process water; that almost all of the industries of Connecticut require large volumes of water suitable for the manufacturing process which each particular industry carries on; that that is more true perhaps of the textiles and paper making, where water of high quality is required; that those industries are more generally located in this state in the eastern end; that the metallurgical industries also use large quantities of water, but require water of less high quality; that as industry in this state has developed it naturally follows that population increases and the population curve shows a steady year by year rise; that the result is that the demands for potable or domestic water supply are constantly growing, so much so, that all over the state of Connecticut practically every city of any size in the state is at the present time reaching out in an effort to develop additional sources of water, and that was one of the reasons for the creation of a Commission, to have some authority over the water resources of the state and to act in an advisory capacity at least as to the allocation of these water resources, because it is now found that municipalities and communities are in competition, and also to meet the situation which will come at a time which is very close, when all of the available clean water sources of the state are developed; that in fact, that time is placed (984) by the engineers as almost here at present; that when economic refers primarily to the necessity of supplying industry with its growing needs for an industrial water supply and the growing population with its need for domestic supply; that the Commission, in its original survey of its problem, found that the domestic sewage of the communities of the State of Connecticut accounted for approximately 85 per cent of the total volume of pollution reaching the waterways; that the Commission has therefore stressed that side of its work; that it is not meant to convey that it had not done a great deal to correct pollution

from industrial waste, but, because of the volume of the domestic sewage and because of the fact that it is a problem that affects every member of the community, it has emphasized that part of its work, and its policy has been to take up, through hearings with the officials of the Communities of the State, wherever pollution is taking place, the necessity of formulating a program for treating that sewage before it is discharged into the waterways of the state; that there has been a considerable degree of success accompanying that effort; that it may be said almost without reservation that every community of (985) any considerable size in the State of Connecticut at the present time is engaged in some stage of the process, varying from the initial stage, which is an engineering survey to show what should be done, up to the point of actual construction of sewage treatment works; that one need go no further than Hartford, where recently, acting on the report of Mr. Eddy, of Metcalf & Eddy of Boston, the city has adopted a program which commits it to an expenditure in excess of $3,000,000 to treat its sewage prior to discharge into the Connecticut River; that New Britain's sewage is entirely discharged into the Connecticut River through the Sebethe (Mattabesset) just above Middletown; that New Britain is at the present time engaged on a rather difficult problem, of deciding just what form of treatment should be put in; that Middletown has appropriated money and is now carrying on a survey; that the program of the State Water Commission contemplates that every community now discharging sewage into the river will be required to treat that sewage; that Thompsonville is now taking the first step; that the town of (986) East Hampton on the other side is holding a special town meeting this week to devote money for their first step; that no community has been neglected; that at the very first meeting that the Commission held, it was decided that the State, when it went to a community and required that community to spend a large sum of money towards treating its sewage, should do so with clean hands, and it at once started on a program of installing sewage treatment plants at all state institutions, and he can name at

the present time only one which has not now been supplied, and for that one there are reasons why it has not been possible, from an engineering point of view, up to the present time, but the Commission started with the Middletown State Hospital on the banks of the Connecticut River; that the State owns a large tract of land on the river at Middletown and had, up to two years ago, discharged the sewage of between four and five thousand people in its raw condition into the river; that that institution is the Connecticut Hospital for the Insane; that the State immediately drew up plans for a modern sewage (987) treatment plant, and it was built under the supervision of the State Water Commission, and has been operated since a year ago last Spring; that it has followed that same procedure at various of the other state institutions, Norwich State Hospital, Mansfield Training School, Connecticut Agricultural College, the Niantic State Farm for Women and various others; that the law explicitly forbids the creation of new sources of pollution, and all plans for sewage disposal have to be passed upon by the Commission; that the last session of the legislature passed an act which charged the State Water Commission with making a comprehensive survey of the water resources of the State of Connecticut; (988) that that survey is now being made; that the act further provided that the report shall be submitted to the Governor this year; that the Commission is showing in this report the necessity for the State to make such a comprehensive survey, including stream-gauging, rainfall, water run-off records, and that sort of thing, and suggesting a method for the administration of the proposed act; that this Commission has been very much interested ever since it learned that it was proposed to divert water from the Connecticut River; that it felt that the Commission had a vital interest, because it was not only that Massachusetts proposed to do this, but that other neighboring states were looking toward certain interstate streams with longing eyes, and it was felt that it was, therefore, a matter of very great importance to it under that part of the law which charges it with supervision of study of the water resources and conservation of such

resources to know what was going on; that the conservation of the water resources of the state includes the cleaning up of streams in Connecticut for the purpose of future water supplies (989) that cities and towns as was pointed out, are already reaching a time when all of the available sources of clean water supply are approaching exhaustion; that in the comparatively near future it will be necessary to go to these larger streams,—interstate streams such as the Farmington, Connecticut and Quinebaug Rivers,—as sources of domestic water supply; that in fact, it can't very well be avoided, if the State of Connecticut continues to grow and develop; that it is thought that Hartford will be the first city that will have to consider using the Connecticut River, and has only recently completed a very large addition to its water supply, but, because of the rapid growth, it now finds itself confronted with the necessity of again increasing its water supply, and it is therefore, in competition with other large cities, growing cities on the same watershed, for a water supply which is limited; that Hartford introduced a bill in the last General Assembly asking for rights to another river, but that it was refused because of the fact that other communities on the same watershed protested so vigorously that it was felt that nothing could be done without very careful study and allocation of the available water supply; that there was created also at the last session of the legislature the Metropolitan District of Hartford, which consists of Hartford and five (990) of the adjoining towns, all uniting in the supply of essential public utilities, such as water, and sewage disposal and a few others, such as intercommunicating highways; that that, of course, has made the situation, as far as Hartford is concerned, more acute, because now it has to supply all of the surrounding towns, as well as Hartford, and some of them are growing very rapidly; that this Metropolitan District includes the subjects of sewage disposal and water supply; that Hartford had accepted a program amounting to something over three millions of dollars for treating its sewage; that that happened about the first of November and in that same week Hartford voted on

whether it would come into the Metropolitan District; that the voters decided that they wanted to come in, and at that time the question of providing for sewage disposal, becoming a District question, passed from the hands of the City of Hartford into the District; that the District is now organizing for taking up its problems and will undoubtedly take it up where Hartford laid it down; that the State Water Commission has discussed the problem of sewage disposal with the Chairman of the District Commission who agrees with its point of view, (993) that New Britain gets its water in a general way from the township or the town of Burlington which lies to the west and a little north of Hartford; that New Britain isn't on the Connecticut—it lies inland to the west a few miles; that the source of supply is a reservoir impounding a mountain stream, and from there the water comes to New Britain; that the sewage goes through a sewage disposal plant that cost the city about a million dollars; that this plant is now inoperative because of certain classes of waste that make it impossible to operate it; so it is practically raw sewage that is discharged first into a small creek and then into the Sebethe (Mattabesset) River, and then into the Connecticut River; (994) that the usefulness of the plant cannot be restored economically; that it is a sand filtration plant, and much of the industrial waste which was principally metallurgical and loaded with iron salts, went into the sewers; that those iron salts sealed up completely and effectively the sand filters so that the sewage runs across the top of the beds into the stream; that the plant would have worked if it hadn't been for the metal salts; that it is a recognized method of sewage disposal; that there is no better method than sand filtration; that the State Water Commission is charged with the cleaning up of the waterways of the State; that its duty is to get the sewage and other forms of waste out of the streams so that they can be used for industrial and domestic purposes; that that is its program; that what has been done in the way of handling the domestic sewage problem has been outlined; that as to industrial wastes, the law requires that the manufacturers shall be told how their

particular wastes can be satisfactorily treated; that that is pioneer research work; that for instance, there is no one that knows how kier liquor (995)—where cotton has been boiled for bleaching—can be treated at reasonable cost; that no one knows what the answer to that question is; that the Yale and Wesleyan University laboratories have been employed, and are carrying on studies of various industrial waste problems, that as the answer to a problem is found the manufacturer can be told what the method is that the Commission wishes to put into effect; that it has been urged to set standards of purification for different streams, but that is not found feasible; that there are certain streams that never can be recovered to the point where they can be used for anything except process water, that is, more or less polluted water; that other streams can be brought to the point where by well-known methods of treatment good potable water can be made out of them; that some of them are so far polluted they are hopeless; that perhaps the Naugatuck River is most heavily polluted for the reason that it is the center of the brass industry and the stream is so filled with copper in solution, as well as acids and other metal salts, that to do anything substantial for it in the light of our present knowledge would mean closing up great industries; that the river is a "nuisance" because, in addition to all this metallurgical waste, it is receiving all the sewage of the valley; that the Commission is pushing ahead with its program of removing the untreated sewage and so correcting this nuisance which now exists, that upon the initiation of the State Water Commission, towns on the river are putting in sewage treatment plants, (996) that this will prevent the river appearing and smelling like a sewer; (997) that from the study or survey of the situation in Connecticut as to what is the more pressing need, purifying water for industrial purposes or getting an additional supply of reasonably pure water for domestic purposes, this need would differ in different parts of the state; that in the more densely populated parts, the domestic water supply is the pressing need, but in certain other parts of the state satisfactory process

water is quite an urgent problem; that all of the textile plants were originally located where they are because the quality of water allowed the turning out of their product; that these plants are largely in the eastern section of the state where there are a number of large rivers; that the Quinebaug is an interstate river which joins up with the Willimantic and one other stream to form the Thames River; that in the case of Hartford, the domestic supply is more apt to be its next problem; that were there only water enough for either the domestic requirement of the community, or for the industrial requirement, generally the domestic is considered the greater need (998) as to priority in the use of the water; that it should be strongly emphasized that the recreational need should be placed very high, possibly ahead of navigation needs; that the president of one of the largest industries in the state, speaking befor the Manufacturers Association not so long ago, made the point that his company, which is a subsidiary of General Motors, required that he explain every time he attended a meeting of the board of directors, why his plant was kept off here in New England, so far removed from its (999) source of raw material supply, that the only convincing argument that he was able to advance was that where this concern was now located in Connecticut he had the best skilled labor supply in the whole United States; and that that was enough to offset all the other economic advantages of moving out into the middle West; that that point having been made, he developed it to show that that same skilled labor today required and demanded certain things in the way of living conditions, such as recreation for their leisure; that as to the recreational value of water, from the point of view of parks and bathing beaches and fishing privileges, he said that if Connecticut did not provide these for its people, it would certainly lose its best asset, which was the skilled labor, because they would go where they could find it, that as to whether the Commission would be disposed to put the recreational value of water ahead even of the industrial requirement, it would seem that the two go together, because if there are no industries, there is no need for skilled

industrial labor; that recreational need should follow closely after the industrial need; that the industrial need is put very high, because industries create the constant population increase in the State of Connecticut; that its industries are constantly expanding in spite of the fact that a great deal is heard about their moving to the South, and a great many of them have done so; that there again, one of the important factors is the shortage of suitable water in New England; that the inability of the textile man to find a suitable water supply has driven him down South to get it, where he is not running afoul of pollution commissions, such as the State Water Commission, to add the overhead of industrial waste treatment to the cost of doing business; that (1000) after recreational and industrial requirements which he would put next to domestic supply, he would put the requirements for power and after that those of navigation.

FISH LIFE

MR. ARTHUR H. FRAZER of Cromwell, Connecticut, a witness for the State of Connecticut, testified (960) that he was not employed by the State; that he had made a study of the Connecticut River so far as the shad industry is concerned; that up to January 1, 1930, his business had been that of a fisherman; that from his view as a fisherman he considered that the flood conditions in the spring in the river had an influence on the shad fisher; (961) that he figured a large freshet cleans out the river thereby purifying the water and it leads the shad into the river; that the water shoots down into Long Island Sound and goes out maybe two miles; that the fish coming up the coast hit the fresh water and it leads them into the river; that ordinarily on an ebb tide the fresh water goes perhaps a mile or half a mile into the Sound and under the same conditions, the freshet goes two miles or further.

MR. JOHN W. TITCOMB testified (961) that he has been superintendent of the Connecticut State Board of Fisheries and Game since April 1, 1922; that he is somewhat familiar with the fishing industry on the Connecticut River; (962) that in his opinion the flood waters have very great effect on shad life in the Connecticut River; that the shad run on the high water; that also formerly perch and striped bass did the same thing; that almost all anadromous fish do; that also trout run to spawning grounds during high water; that the state operates two shad hatcheries and a perch hatchery on the Farmington and Salmon Rivers which are tributaries of the Connecticut; that he finds from experience that the waters from the tributaries of the Connecticut River have an influence on the fish life in the river; that they all contribute towards the clear cold water of the river and have something to do (963) in regulating the temperature and a good deal to do with regulating the flow; that he has no doubt that any diversion from

those streams will adversely affect fish life to some extent; that under his administration the state first began to propagate shad; that the catch of shad and the artificial propagation from 1923 to 1929, both inclusive, was as follows (964):

Year	Catch	Fry Released
1923	13,350	609,000
1924	25,316	3,723,000
1925	43,365	3,824,500
1926	37,177	4,514,000
1927	34,321	6,613,000
1928	56,191	14,912,000
1929	91,597	18,833,000

that the last high figure in catch is attributable to artificial propagation; (964) that it takes four years from the time of putting the fish in the stream to get results; that if the flood water is high and the temperature is high early in the season, the shad get in the upper waters, and the upper river fishermen get the best fishing; on the other hand, if the season is late, the lower river fishermen begin to catch them before the upper river fishermen do, and they have got to get by the lower nets to give the upper river people any; that whether they get upstream is dependent on the flood water, that is what attracts them; that a reduction in the flood would be harmful to the fish life; (965) that he could not tell how much of a reduction would affect them but any change in water conditions will; that he had this experience for forty years; that the flood varies from year to year some seven or eight feet; that he doesn't know as he can say that the run of fish varies in direct proportion to the floods but ordinarily the best years of fishing are with the high flood conditions; that generally speaking the records would show that the bigger the flood the bigger the catch but not always because some years there is an adverse weather condition; for example ten days ago there was very hot weather; if that condition had come on early in April, with the high water that always comes with that kind of weather,

from the melting snows, he thinks the shad would have come up the river; then last Sunday's cold snap, would simply turn the fish right back and keep them back so they might not have come in at all; (966) that they might not ever come back up as a result of that, and it might have left them egg-bound, and that means there would not be as good reproduction; that while formerly shad ran up the Connecticut River as far as Bellows Falls, Vermont, they now are confined to the State of Connecticut because of the dam at Enfield; that they cannot get over a dam; that shad will not take a fishway; that it is the only species of the anadromous fish that won't take a fishway; that no fishway has been devised that would allow shad to pass; (967) that the limit of their upstream passage is the first dam they come to; (967) that the percentage of shad would be more or less uniform in proportion to the size of the flood; Q. Would the effect of it be in proportion to the amount of water diverted? A. Probably—that is sort of difficult to answer; (968) that a three inch diversion from a 25-foot flood wouldn't have as much effect as a five foot variation from year to year; (although the witness stated he understood Massachusetts would make a diversion at any flood height) (969) that his feeling is very strong that any (970) change, by taking out the clear water of these tributaries, is going to adversely affect the run of fish, and their natural reproduction in these low waters; even so little as 2%, every drop; that he doesn't think any human being can tell just what these differences are but the diversion would take out of the river the clear waters of a pure stream which has the even temperature which fish like, every drop of which will affect the river. That his commission in 1925, after an investigation, published a report which said that in general the Connecticut River and its lower tributaries are favorable for shad migration and propagation but parts of the Connecticut River show bad pollution chiefly due to the sewage of Hartford and Middletown; that the sewerage from one large hospital at Middletown has since been removed from the river; (972) concerning the pollution of the river, his theory is that if there were no floods, the pollu-

tional conditions would be such that the shad wouldn't come up; that every spring the floods clean out the river and clean out these sludge beds and then comes the run of shad; that the shad don't come up all in one rush; they come up to one of these holes and rest in there (973) and then in the evening they start on up again; that when they get to a spawning area, they remain in that until after dark, and then start off into the swift water to spawn; that they spawn in the strong water; that that is the reason they need the flood water; that attracts them up, and they always go into the rapid water to spawn; that some shad are caught on the way down but mostly on their way up; that the State of Connecticut licenses the fishermen and regulates the industry; that the licensed number of nets has varied from 80 to 103 in recent years; that in these recent years where they have been observing this more particularly, the runs, as a rule, are larger on the flood, high floods; it is not a rule, however, to which there are no exceptions; (967) that May is the big month for shad; that a comparative showing of May floods and shad catch from 1913 to 1929 (Exhibit C-29) shows that they correspond in a general way except in the years 1922 and 1923; that Exhibit C-30 shows the total catch of shad, number of nets and pounds and fry produced by the state from 1872 to 1929 inclusive; (979) that the explanation of the small catch in 1915 and the large catch in 1919 might be that in 1915 there was a favorable hatching season and not many fish, or that the fish got by the nets up to the spawning ground and were not caught, or that in 1919, there was good natural reproduction, or that the prices were high and they fished night and day instead of fishing in a desultory way; that 1919 was the best year from 1913 to 1929; that you cannot always tell from a year how it happened that there appeared to be a larger run that year.

MR. JEREMIAH E. BECKWITH, of Saybrook, pilot and steamboat master, a witness for Connecticut testified (848) that the best effect of the 1927 flood was that it cleaned the river

out and twice as many shad were caught down on the lower end of the river than had been caught before in quite a number of years.

DR. WILLEM RUDOLFS, an expert witness for Connecticut testified (434) that if the amount of oxygen in the river is insufficient, fish life is affected; (435) that there is a higher oxygen requirement for fish life than to prevent nuisances; that certain fish require more oxygen than others; that eel, carp and catfish require less dissolved oxygen than fish like bass, pickerel and trout which like cleaner water; that the amount of oxygen required for fish life like shad is a minimum of 3.5 to 4 parts per million; that when the dissolved oxygen is lowered beyond this point, the fish begin to migrate, if they can, or if they cannot they begin to suffocate because there is not sufficient oxygen in the water for them to live; that, explaining Exhibit C-19, the upper line shows the dissolved oxygen throughout the summer, the broken line labeled oxygen balance shows the surplus of oxygen available, and the line labeled b.o.d. is the 5 day bio-chemical oxygen demand; (441) that fish in order to live need an amount of oxygen of 3½ to 4 parts per million; that is where the balance comes in; that there were a number of days that the river was so polluted, as shown by the oxygen balance on the exhibit at the state line that fish like shad must either migrate or die, that the oxygen balance as given at the last column on the right hand corner of Exhibit C-19 (442) shows that the oxygen balance was for a number of instances less than the oxygen required by the fish, if the river is used for oxidation of the sewage polluted material; (443) that the results of his studies as to fish life in the Connecticut river at the state line show that there were a number of days in which the river was so polluted at the state line that fish like shad, which is an indicator for this particular river, would either have to migrate, or, if they could not migrate, would have to die; that the lowest weekly average oxygen balance was 3.58, the week

of August 25-31, 1929; that 3.58 was on the border line; (449) that 4.08 is on the border line at which they start to migrate, just as much as 3.58; that the question of the number of days a fish has to be subjected to a certain oxygen condition is an entirely different story; that it is the amount of dissolved oxygen that determines the migration or possibly the life of the fish, not the oxygen balance; (578) that the figures as to oxygen at Hartford indicate that fish could live as conditions are just above the border line, at the time of average summer dry weather flows; (490) that the average flow of the Connecticut River at the State line for the period July 8th to September 14th, 1929 was 5,050 cubic feet per second; (491) that had the Massachusetts project been in effect during the period July 8 to September 14, 1929 (the period the witness had been speaking of in his testimony), there would have been no water diverted from either the Ware or Swift Rivers; but under the War Department findings, there would have been an improvement in the Connecticut River at the state line, (492) because of the release of pure and potable water from the Swift River Reservoir in addition to the normal flow in the river; (500) that with reference to Exhibit D-2 if the average flow of the Connecticut river had been 3,000 cubic feet per second and if there had been an average release from the Swift River reservoir of between 5 and 54 cubic feet per second on an average of 45 cubic feet per second, there would have been an increase of 1½% in the flow of the Connecticut River at the state line and an improvement in its quality.

MR. ROBERT SPURR WESTON, an expert witness called by Massachusetts, testified as follows:

> (1404) Q. "Have you or have you not any opinion on the effect of pollution and the effect of our (The Massachusetts) diversion as to fish life in the Connecticut River? A. I think it is entirely immaterial except as it may slightly raise the oxygen content in certain dry

months when the amount let down would be more than we have observed during the 14 months. There are, of course, dryer months than we observed, and during those months a release, under the rules of the War Department, would have some effect in improving the river. Generally, I think the effect would be immaterial."

MR. FRANK E. WINSOR, chief engineer of the Metropolitan District Water Supply Commission, an expert witness for Massachusetts, testified (1437) that he had prepared a diagram showing the shad catch in the Connecticut River in relation to May floods from 1880 to 1929 inclusive, basing the shad catch on the report presented by Connecticut and the record of May floods at Sunderland, Massachusetts by the United States Geological Survey and the records of the Holyoke Power Company; Exhibit C-29 (a); (1439) that this exhibit and exhibit D-12 (arranging the floods year by year in order of height) show that the highest catches have not corresponded to the highest May floods but rather the opposite is indicated; that the lowest catch happened at the time of the highest floods and the highest catch occurred when the flood was only moderately above the low point; that instead of the highest catches coming at the time of the highest flood, we get a higher catch at the lower flood.

WATER SUPPLY AND DEMAND IN EASTERN MASSACHUSETTS

It is agreed by both Connecticut and Massachusetts that the following statement may be taken as true.

Boston and the surrounding Metropolitan area are faced with a serious water shortage in the near future and there is a real necessity for their making provision for a large quantity of additional water which will meet the needs of the people of this region for a considerable number of years. The Metropolitan area consists of 20 cities and towns, and 15 other cities and towns are eligible to become members. These 35 cities and towns have a population of about 1,900,000. Other cities and towns must be considered in intimate connection with the Metropolitan District, because first they are likely to depend on the District Water Supply at some future time and secondly if the Ware and Swift waters are denied to Boston all the population in the northeastern part of the State must divide up existing water supplies. In this view the needs of the population of northeastern Massachusetts taken as a whole must be considered. The total population thus concerned is now 2,860,000, estimated likely to reach a total in 40 years of 4,572,000. The use of water is increasing and population is increasing. Dry seasons have occurred when the Metropolitan District has been imminently close to water shortage. Massachusetts witnesses stated that in 1970, owing to disuse of some of them, the present supplies will probably have decreased about 54,000,000 gallons per day and the consumption requirements will probably have increased from 244,000,000 gallons per day to 467,000,000 gallons per day, and that there will be a deficit of 178,000,000 gallons per day. The southeastern part of Massachusetts, including Cape Cod, seems to have sufficient supplies of water for itself and was not brought into the case.

It is agreed that the following table properly represents the total water consumption requirements in million gallons per day of northeastern Massachusetts in 1929, 1970 and 2000:

	1929	1970	2000
18 towns in Metropolitan District supplied with water	139		
2 towns in District not supplied with water by the District	8		
TOTAL	147	265	
15 towns eligible but not now in District	24	50	
10 towns just outside District	4	8	
20 towns further west	22	50	
TOTAL	197	373	511
18 towns in Ipswich group	22	47	70
37 other towns in potential group	25	47	72
TOTAL	244	467	653

It is also agreed that the following table represents accurately the amount of water in million gallons per day which Massachusetts witnesses stated is available and will be available in the years 1929, 1970 and 2000, in northeastern Massachusetts, excluding from consideration the Ware and Swift supplies:

	1929	1970	2000
18 towns in Metropolitan District	147	134	129
2 towns not supplied by the District	8	0	—
TOTAL	155	134	
15 towns eligible	27	18	
10 towns just outside	4	0	35
20 towns further west	22	20	
TOTAL	208	172	164
18 towns Ipswich group	13	6	0
37 towns potential group	37	26	22
TOTAL	258	204	186

Ipswich River (Hazen recommendation, not developed but available as a supply)	70	70	70
Assabet River (not developed but available as an emergency supply only)	15	15	0
TOTAL	343	289	256

It is also agreed that the following table represents the amount of water in million gallons per day which witnesses for Connecticut stated is now available for northeastern Massachusetts in addition to the supplies now developed by Massachusetts:

1. Fifteen Watershed Plan:		
A. Shawsheen-Ipswich development		
1. For Metropolitan District	78	
2. Reserved for local sources	22	
		100
B. South Sudbury Filters (in addition to present supply)		17
C. Lower Sudbury—Hobbs Brook		27
D. Assabet		35
		179
2. Merrimac River		200
TOTAL		379

It is further agreed that the following findings of the Special Master are correct:

> (Page 48) "So far as cost is concerned, there is no vast difference between the schemes and any of them is within the means of Massachusetts."
>
> (Page 52) "I have not gone into the comparative costs of the various projects because I think it is immaterial. There is no such wide divergence in cost as to make it a determining factor."

MR. NATHAN B. JACOBS, an expert witness for Connecticut, testified (1009) that he had made on original investigation of the water needs and available sources of supply in Eastern Massachusetts for the Boston Metropolitan District; that his study comprised an independent survey of all of the data which an engineer would consider necessary in connection with an investigation for water supply for the Metropolitan District; that this included population studies, use of water studies, present available facilities, and sources of supply which could be developed economically for a water supply for this District; that the Metropolitan District at present comprises twenty cities and towns in the vicinity of Boston and there are eligible to it fifteen additional cities and towns within a ten-mile radius from the State House at Boston, which might, within the next 30 or 40 years, become takers of water; (1010) that the cities of Lynn and Saugus, which are eligible for membership in the District, would probably not become users of Metropolitan District water within the next 30 or 40 years because of the adequacy of their own independent supplies; that Dr. Winsor's figures for the amount of water required to supply the 33 cities and towns eligible for membership in the District, excluding Lynn and Saugus, of about 315 million gallons daily in 1970, check very closely with his own figures; (1011) that for all practical purposes the demand which should be considered is between 300 and 315 million gallons daily for 1970 for all of the cities and towns in the District excluding Lynn and Saugus; (1023) that

> "we went at the investigating of eastern supply very much as an engineer or anyone would go at investigating the question of a water supply for a community or a group of communities, and we made a survey, going around through the state, the study of maps, the study of documents, getting leads from various sources";

(1024) that the investigation of possible sources of supply in Eastern Massachusetts for the Boston Metropolitan District to which he is testifying was made by

the organization of Morris Knowles Incorporated; that it included the study of practically all the sources of supply which had been investigated and reported on by others; that the work of Morris Knowles Incorporated was reviewed by Dr. F. Herbert Snow, Chief Engineer of the Public Service Commission of Pennsylvania, by Langdon Pearse of the firm of Pearse, Greeley & Hansen, Consulting Engineers of Chicago, by Dr. John H. Gregory, Consulting Engineer of Johns Hopkins University, Baltimore, Maryland, by Major Ezra B. Whitman, Consulting Engineer, of Baltimore, senior member of Whitman, Requardt and Smith, by Professor C.-E. A. Winslow of New Haven, and by Dr. Willem Rudolfs of Rutgers University, New Jersey; (1025) that these gentlemen went into the field following the first preliminary survey and on the basis of their field inspection, survey parties made field investigations of each of the sources of supply which had been agreed upon as a likely source for the Boston Metropolitan District; that the results of this work were brought into the office, plotted, studies made, preliminary plans drawn in some cases, estimates of cost prepared, analyses of water made, and this work was further reviewed by the Consultants; that the investigation included first a preliminary visit for selection of reservoir sites; (1026) that on the basis of that preliminary investigation, field parties were put out to make the surveys; that practically all of the Consultants went over the ground while these survey parties were in the field; (1027) that after the major portion of the surveys were completed, the sites were again visited, looking over the project with the surveys in hand; that conferences have been held from time to time; that the results of the investigation and conferences indicated quite clearly that the best supply that the Metropolitan District could obtain would be from the Merrimac River; that there is practically an unlimited supply for a great many years available in that river; that records were obtained as to the run-off of the river; that water analyses as published annually by the Department of Health of Massachusetts, were studied and supplemented by his own analyses, chiefly on dissolved

oxygen, biochemical oxygen demand, and carbon dioxide; that in view of all the considerations of this supply against any of the others, it appeared to be the very best supply available for the Metropolitan District; (1028) that he proceeded to investigate methods for purifying, conveying and delivering the water to the Metropolitan District and made preliminary plans and estimates of cost to see, first, whether it would be feasible and proper, and, second, whether the cost would be reasonable and within economic limits; (1029) that the drainage area of the Merrimac River at Tyng's Island, the proposed point of taking, just above Lowell, is 3,819 square miles, net, after excluding the drainage area of the Nashua River now developed as the Wachusett Supply, so-called, and used as a water supply by the Metropolitan District; (1030) that the average flow of the Merrimac River at Tyng's Island is 5,706 cubic feet per second, which is equivalent to about 3,700 million gallons daily; that the minimum monthly flow available by drawing down the pool above the Lowell Dam would be about 650 million gallons daily; that the average flow of the Merrimac, 5706 cubic feet per second, is about one-third of the flow of the Connecticut river at the Massachusetts-Connecticut state line; (1031) that the proposed plan for taking water from the Merrimac River contemplates the construction of intakes in the river at Tyng's Island, a pumping station well above the maximum flood height which is approximately 105 feet above sea level; that the capacity of this intake and of the entire project was assumed for purposes of investigation and design to be 200 million gallons daily; that this figure of 200 million gallons daily was selected because it was approximately the amount of water which the Metropolitan District proposed to develop from the Ware and Swift; that it was not because the yield of the Merrimac River is limited to 200 million gallons daily, nor because the Metropolitan District needed that amount at this time, but a plan was wanted which looked to about the same point for safe yield of water supply as the Ware and Swift project; (1032) that in a general way, summarizing the investigations which were made as to the quality

of this water, it is that of a river carrying a considerable amount of industrial and domestic wastes; that the equivalent population on the watershed of the Merrimac River above Tyng's Island is between 400,000 and 500,000 persons; that he looked particularly for those qualities of a water supply which affected the problem of treatment, as to whether there was anything in it which would limit in any way the use of this water under ordinary improved methods of water purification; that the 1928 report of the Department of Health of Massachusetts showed that the average number of bacteria per cubic centimeter at the Lawrence intake, which is several miles below Tyng's Island, was 210; that the significance of this figure may be judged by a comparison with the bacterial content of the raw water used as a source of supply in American cities of over 100,000 population, having a filter plant; that there are 41 such cities, and records were available from 35; that 5, namely, Providence, R. I., Detroit, Mich., Hartford, Conn., Cambridge, Mass., and Buffalo, N. Y., had lower bacterial counts than the Merrimac River in 1928; (1033) that 30 cities are using water supplies having, before treatment, a higher bacterial count than the Merrimac River in 1928 and that these include some of the outstanding cities of the country, in regard to the question of good, pure, safe, potable water; that the color of the Merrimac River water is high compared to the color of some of the water that he deals with, particularly in the central part of the country; (1034) that most of the Massachusetts streams are high in color; that the Ware River water before treatment or storage has a color of 57; that color can be removed and reduced; (1036) that the color of the Quinepoxet River, tributary to the Wachusett Reservoir, has a color of 38; that the Swift River at West Ware, below the confluence of the three branches of the stream, has a color of 30; (1037) that the hardness of the Merrimac River water was 17 parts per million which, with the exception of the water supply at Providence, R. I., is lower than that of any of the 17 cities of over 100,000 population where the data were available; (1038) that the results of his engineering studies con-

vinced him that this was a very good water for purification for a public water supply; (1039) that Exhibit C-31 shows a general plan of structures for the development of a water supply from the Merrimac River; that the pumping station was considered to have a capacity of approximately 200,000,000 gallons a day, though he put in 300,000,000 gallons a day pumping equipment with the idea that in case the largest unit was out of service there would still be a capacity of 200,000,000 gallons a day; that from the pumping station at Tyng's Island pipe lines lead to Foster Martin Reservoir; that the water would be pumped against a total head of about 76 feet; (1041) that this reservoir is designed for storage and will be kept filled; that it would have a capacity of about 18 billion gallons; that this is a natural reservoir site capable of development by building a dam and dike about existing ponds known as Foster's pond and Martin's Pond; (1042) that this site was found to be fairly well on a direct line between the point of taking the water at Tyng's Island and the final delivery point in the Metropolitan District at Spot Pond, which is a presently-used distribution reservoir of the District having a very large capacity, capable of equalizing any fluctuation in the hourly or weekly demand of the system; that the Foster-Martin Reservoir would hold the water for a period of days in order to provide storage for preliminary treatment of the water from the river; that storage is the only treatment and purification now used by the Metropolitan District; (1043) that the reservoir would be baffled by building a dike, so that the water would have to travel in the reservoir the entire distance from the point of inlet to the point of outlet; that this preliminary treatment by storage would remove practically all of the bacteria and considerable of the color and furnish at the outlet a water very easy to treat at a modern filtration plant; that this reservoir provides a storage period of 90 days; that it reduces materially the loading on the filter plant; (1045) that eighteen billion gallons is the total capacity; that he considered no draw-down, nor any loss from evaporation; that, in other words, he considered it purely as a storage purification; that

storage is the method of purification that has been used primarily on the Metropolitan District supplies and on a great many supplies; (1046) that intestinal bacteria die off very quickly and it would be fair to state that 85 to 90 percent of them would die within the first 3 or 4 days of storage; that by the end of two months, 99 percent of the intestinal bacteria entering the reservoir would have died, showing the enormous purification that takes place just by storing water; that he does not believe that in any supply this should be the only safeguard of the purity; that there should be other protection to the purity of any water supply used, particularly if the source of supply is at all subject to contamination; (1047) that practically all of the organic material contained in industrial wastes would be removed by the storage proposed in the Foster-Martin Reservoir; that nevertheless, the filtration plant has been laid out so that all the protection which would be necessary even for the most polluted supply would be provided; that the water would be aerated, treated chemically for coagulation, filtered, and chlorinated; that the aerators and filtration plant would be located about 3,000 feet away from and below the Martin Pond Dam; that there will be four units of aerators ultimately, each unit being able to take care of about 50 million gallons per day; (1048) that from the aerators, the water would pass to mixing chambers; that the mixing chambers provide a retention period of about 20 minutes; that these chambers would be of the "around-the-end" baffle type so that the water travels criss-cross through the chamber at the rather rapid velocity of about one-half foot per second; (1049) that above the chambers is located the chemical feeding machines and facilities for introducing lime and alum into the water; (1050) that provision is made in the plant for pre-chlorination; that after leaving the mixing chamber, the water passes into the coagulation basins which provide a detention period of about 4 hours and the capacity of the basin is such that the water passes through at the rate of 1.1 feet per minute; (1051) from the coagulation basins, the water would be taken onto the filters which are of the rapid sand or mechanical

type; that this type was adopted chiefly for its color removing propensities; (1052) that spare units are provided in the filter plant in case a few units are taken down for cleaning or for resanding or for any other purpose; (1053) that the filter units are made in the form of a concrete box 30 feet wide by 48 feet long on the bottom of which is a manifold, or a collecting system of pipes; that on top of the manifold is coarse gravel, then fine gravel, and finally about 30 inches of sand and on top of that about 4 feet of water which would come over from the coagulating basin; that this is the usual process of rapid sand filtration used continuously in America for about 30 years and is now almost universally adopted; (1055) that this filtration plant is different than the one built at Lawrence, Massachusetts which is of the slow sand type; that the filters at Lawrence take the water out of the Merrimac River in the City of Lawrence directly onto the slow sand filters; that these are large units made up similar to the rapid sand filter units in that they have sand, gravel and an underdrainage pipe system, but instead of passing the water rapidly through at the rate of 125 million gallons per acre per day they pass the water at only about 3 million gallons per acre per day; that no coagulation is used but dependence is placed entirely on the so-called schmutzdecke which is formed about the sand grains; when the filters become clogged so that the water does not pass through even at the rate of 3 million gallons per acre per day, the units are shut down and the filters are scraped, the sand washed and replaced on the filters; that in the mechanical or rapid sand filter type the washing of the sand is accomplished without removing any of the sand from the unit by reversing the flow of water through the filter from a downward to an upward direction; (1056) that in washing, the water passes up through the gravel and the sand and overflows into a drain and that carries out any sediment or deposit which has accumulated during the time the filter has been in operation; that at Lawrence there is no storage and no sedimentation preliminary to filtration; that the water at Lawrence is good water; (1057-1058) that from the filtration plant at Foster-Martin Reservoir,

the water would be pumped by a high lift pumping station to Spot Pond in the Metropolitan District; (1060) that a 200 million gallon per day filter plant would not be necessary at the present time, that the installation of some pumping units could be deferred, also the construction of some filters, coagulation basins and one-half of the filtered water reservoir; (1063) that after treatment, the quality of the water from the Merrimac River would be equal to the quality of the best water supplied anywhere; that it would be better than the present Boston water supply; that additional sources of supply were studied in Eastern Massachusetts but if the Merrimac project were adopted additional supplies would not be required; that he thinks that the supply from the Merrimac River is unlimited; (1064) that in the examination of supplies other than the Merrimac River, the first thing that occurred to him was the conservation of the present supplies; that merely because certain supplies have become polluted they should not be abandoned; that it would be well to conserve them by filtration and purification; that if filters were installed on the Sudbury supply immediately a greater yield could be relied upon from the existing sources; (1065) that the entire Sudbury area has not been developed because, as explained by Dr. Winsor, there is (1066) some pollution on this watershed; that filters have been recommended by others; that he thinks that a filtration plant at this point would be a very decided step in the direction of utilization of the present supplies; that the most important supply outside of the Merrimac is a development of the Ipswich River supplemented by the Shawsheen River, in what he has termed the Shawsheen-Ipswich development; that this is a comparatively good development and a large one, developing a water supply of more than 100 million gallons per day; that two large storage reservoirs would be constructed on the Ipswich River and three small reservoirs on the Shawsheen River; (1068) that the total drainage area which would be developed on the Ipswich River would be 121 square miles; that in developing this river it would be economical to develop with it the Shawsheen River; that the water from the reservoirs

on the Shawsheen would be pumped over the divide between the Shawsheen and the Ipswich into the latter river; (1069) that the water would flow down the Ipswich River through the two reservoirs on the Ipswich to the filtration plant and pumping station, located on the Willowdale side of the lower Ipswich reservoir; (1070) that the Ipswich River is considered part of the water supply for Lynn and Saugus which have not been considered a part of the Metropolitan District even in 1970; and that there are other cities and towns in the immediate vicinity that could well be supplied from such a large development as that proposed on these rivers so that of the 100 million gallons per day developable yield from the Shawsheen and Ipswich 78 million gallons per day would come into the Metropolitan District and the balance would be reserved for use by local communities; (1071) that 23½ million gallons per day would be reserved for the local communities; (1072) that this is the amount of water that they would reasonably be expected to require in 1970; that the additional yield by the development of the Sudbury filters would be 17 million gallons per day; (1079) that the next project considered for development was the enlargement of the present Cambridge Water Works system and its development into a larger supply by increasing the elevation of the present reservoir on Hobbs Brook and augmenting the small drainage area of Hobbs Brook by pumping water from the Sudbury River at a point above Concord into the enlarged Hobbs Brook Reservoir; that this would increase the yield by 27 million gallons per day; that Cambridge will be in the Metropolitan District long before 1970 and therefore this would be a logical increase of the facilities and of the watershed that they have; (1080) that this water comes primarily from the Sudbury River and is called "Lower Sudbury" in his work as distinguished from the other references which have been made to the Sudbury such as North Sudbury and South Sudbury; that the water which would be collected is that which runs off the drainage area of the Sudbury river below the present reservoirs in the Metropolitan District; (1081) that the next development con-

sidered was the filtration of the Wachusett supply; that it appeared to him that with the passing of time and the growth of population on the watershed, particularly on the Wachusett, filtration of Wachusett water must be contemplated within the next 40 years; that he considered that a filtration plant would be built below Sudbury Reservoir No. 5; that Boston will eventually come to the filtration of the Wachusett supply unless additional property is purchased to protect it; that it is possible that if the Merrimac River were developed Boston could retain increasingly large amounts of water for storage in the Wachusett Reservoir and rely on storage as they do now, with the addition possibly of chlorination; that in the economic development of these present resources Wachusett water and Sudbury No. 5 reservoir water will be filtered and when that is done it will be possible to increase the supply still further by developing the head waters of the Assabet River, the Assabet being that stream which lies between the watershed of the Nashua and that the Sudbury and joins with the Sudbury to form the Concord; that the Wachusett aqueduct carrying water from the Wachusett reservoir to the Sudbury reservoirs passes through this drainage area; (1082) that in general, the diversion of water from the Assabet would be from the smaller drainage areas of the head-waters; (1084) that the development on the Assabet River is from 9 small water sheds, totalling 58.8 square miles of drainage area; (1083, 1084, 1090) that these nine small watersheds have respectively drainage areas, capacities, and elevations as shown in the following table which summarizes the data testified to by the witness on these pages. The letters designating the watersheds correspond with those shown on complainant's Exhibit C-32.

Water-shed	Drainage Area	Capacity of Reservoir	Elevation
A	11.3 sq. mil.	212 million gallons water to be pumped into Reservoir B-1	230
B-1	5.3 sq. mil.	848 million gallons water pumped to Wachusett Aqueduct	330
B-2	4.3 sq. mil.	716 million gallons water flows into Wachusett Aqueduct	330
C	15.1 sq. mil.	38 million gallons water pumped into Wachusett Aqueduct	230
D	1.6 sq. mil.	65 million gallons water to flow into Wachusett Aqueduct by gravity	325
E	4. sq. mil.	48 million gallons water to flow into Wachusett Reservoir by gravity	300
G	6.5 sq. mil.	193 million gallons water to be pumped into Reservoir E	300
H	7.7 sq. mil.	264 million gallons water to be pumped into Reservoir I	320
I	3. sq. mil.	180 million gallons water flows by gravity into the aqueduct	280

(1085) that the total yield, including present sources, would be 304 million gallons per day available for the Metropolitan District after deducting water required by local communities from the Ipswich River; (1086) that the increased yields over the present supply would be 157 million gallons per day; that an examination of analyses of water from each of these sources of supply during 1928 and 1929 indicates that the water is of such a quality that it could be treated without difficulty by filtration; (1087) that there is no good reason why these waters cannot be filtered and used; (1333) that he considered the Merrimac project preferable to that from other sources in Massachusetts described as the "Fifteen Watersheds Plan"; (1334) that he did not propose to draw at once 200 million gallons per day from the Merrimac River, but he would still keep all the present sources of supply which the

Metropolitan District had and supplement them by the Merrimac River; that his plan was for a water works capable of drawing 200 million gallons per day from the Merrimac River when that amount was needed; that the Foster-Martin storage reservoir was intended primarily for purification purposes, but the storage was equal to 18 billion gallons which was considerably longer storage than was economically required ahead of filtration so that there would be a possibility of some drawing down there to equalize the monthly flow of the Merrimac River; that he didn't consider any draw-down in his plans for the project but that a draw-down is possible; that it could be drawn down to 10 billion gallons without defeating the purposes for which it was planned, and it would still perform its functions satisfactorily and with the same hygienic results; (1335) that the idea was to find a good storage reservoir with anywhere from 30 days' storage up and he found one of 18 billion gallons capacity and it was decided the longer storage period probably would not hurt; that some people might think that 60 or 90 days' storage was better than 30 days' storage. (1337)

Q. What? A. We had one site that is even larger than that, but this site seemed to meet all of the requirements.

Q. But your general plan is to keep it full, isn't it? A. Yes. A great many years.

Q. What did you find the low flow on the Merrimac River at your intake point? A. May I have one of my boys give me the copy of the statement which I have just handed to you?

Q. Yes. A. The low flow of the Merrimac River, based upon the discharge measurements at Lawrence, Massachusetts, which is below the Tyng's Island, was the month of July, 1911, when the average flow per square mile was reported as .266 cubic feet per second.

Q. Give us that again, please. A. .266 cubic feet per second per square mile of net drainage area. The reason I emphasize the word "net" is because the Government reports the flow as gross and net, the deduction being for the Wachusett and Sudbury areas, which are considered as bein "out" in the net flow.

Q. Well, they are out as far as the Merrimac is concerned, I suppose aren't they? A. With the exception of the dry weather release, they are out. And that dry weather release is accounted for separately on the Merrimac River gauge at Lawrence, Massachusetts. So that, taking those figures out, that is, taking out both the land there and the dry weather release there, the Government calculated the figure of .266 cubic feet per second per square mile.

Q. Would that be increased by the release? A. Slightly.

Q. Do you know how much? A. Well, when I used the word "slightly" (1338) it should have been explained. If we were reporting really a flow in cubic feet per second per square mile, if we include the release and also include the mileage, why it will decrease the yield per square mile. But it is a very small quantity and we disregarded it.

Q. I see. So you took the .266? A. We took the .266.

Q. Can you translate that into cubic feet per second or into gallons or something else? A. That was equivalent to 660 million gallons per day, average for the month of July, 1911, at Tyng's Island.

Q. Was that for the whole month or a single day? A. No, that is for the whole month.

Q. That is average for the month? A. That is average for the month, and we considered that that was a fair indication, because, with two billion gallons storage, that could be equalized throughout the month.

Q. How would you equalize it? We are not talking about the period when you need two hundred millions a day? A. Well, we are talking about the period when we might need the 650 million gallons a day. It is quite a long time off, and with two billion gallons in storage you could equalize the flow of that month so that you would be able to have an average flow for the month, each day, of six hundred sixty millions of gallons.

Q. In the river? In the river? A. From the river, yes.

Q. From the river? A. Yes.

Q. You don't mean that you could divert that amount from the river, or do you? A. You could divert it, yes.

(1339) Q. Six hundred and fifty million gallons a day? During that month you are speaking of? A. Yes,

if you are going to take every drop of water that is in the river.

Q. If you are going to? A. Yes.

Q. If you are going to, but you don't need to, do you? A. We are talking about the total flow of the river, as I understand.

Q. Yes, I am talking about the total flow; you say it averaged 650 million a day? A. 660 million gallons a day, at Tyng's Island.

Q. Yes, and that therefore it would be possible, every day, to take that number of gallons? A. Yes, with a storage reservoir of two billion gallons.

Q. And where is that reservoir? A. Well, there is a storage of almost two billion gallons in back of the Pawtucket dam at Lowell.

Q. Is that the dam of the locks and canals people? A. Yes. I considered that flow, if the time ever came when the city of Boston or the Metropolitan District, or the State of Massachusetts needed the whole flow of the Merrimac River, that you could get your two billion gallons storage at that time.

Q. Out of that mill pond? A. Well, you would get it some place else. I wouldn't think you could get it out of that mill pond, no. I merely mentioned the mill pond to show how small an amount of storage the two billion is, to equalize that flow.

Q. You would either get it from there or provide it somewhere else? A. Yes.

Q. Well, supposing you take it from there, would there be any water left in the mill pond? A. No, I don't think there would (1340) if you are going to assume that sort of a condition.

Q. Well, that was the condition you were assuming. A. No, I am not assuming that you are using that mill pond. I merely mentioned that mill pond to give you an idea of what two billion storage is.

Q. Well, I understand you would have to use some storage somewhere to get your water, wouldn't you? A. To get 650 million gallons a day.

Q. Yes. A. Yes, indeed.

Q. How about two hundred million? A. None.

Q. What? A. I don't think we would need any. Well, I will take that back. During that time there were several days when the flow was less than two hundred million gallons a day.

Q. So that if you took two hundred million gallons on those days would you take it from that mill pond? A. Yes,—Let me explain why. These measurements are made at Lawrence.

Q. Lawrence? A. And when the river was low, which I assume was the two Sundays during the month, that the extreme low times occurred, the flow at Tyng's Island was probably greater than the proportion of the flow which passed Lawrence, the storage being held back in Pawtucket dam, so that probably the flow at Tyng's Island was greatly in excess of the amount which I have computed by taking the proportionate drainage area to Lawrence. (1341)

Q. Well, as you compute it, what is it? A. Sir?

Q. As you compute it, what is it? A. The lowest figure which I computed was the 23d of July, which was only 54,000,000 gallons per day. That was based on 98 cubic feet per second at Lawrence.

Q. And on that day you would rely on the mill pond for the balance of the water? A. If there was only 54,000,000 gallons coming.

Q. You do not think there was very much more, do you? A. Yes; I imagine there was considerably more.

Q. Do you imagine that there was 200,000,000 gallons? A. More than 200,000,000.

Q. You think the flow at Tyng's Island was as much greater than at Lawrence? A. Yes, because the flow on Saturday was 445,000,000 gallons, the flow on Sunday was 54,000,000 gallons per day, and the flow on Monday was 715,000,000 gallons.

Q. That is all at Lawrence? A. This is at Tyng's Island, based on allocating Lawrence. Putting it the other way, the flow dropped from 805,000 cubic feet per second on Saturday at Lawrence to 98 cubic feet per second, and increased on Monday to 1,296 feet per second, showing that the water was being held back and piling in back of the Pawtucket dam.

Q. The last figures were at Lawrence? A. Yes.

Q. Your computations at Lawrence were what for those three days? A. My computations at Lawrence were 445,000,000 gallons on Saturday, 54,000,000 gallons on Sunday, and (1342) 715,000,000 gallons on Monday.

Q. I suppose in your computation you took into consideration the probability that the big dams up in Manchester were holding back water on those days? A. Well, that is possible too.

Q. That would affect the flow of water at Tyng's Island, wouldn't it? A. Yes, sir.

Q. Those dams are not in Massachusetts? A. That is true. I did not give the matter very much serious consideration because of the fact that we could on that day pull down a few hundred million out of the Pawtucket dam or we could pull a couple hundred million out of the storage of 18,000,000,000 at the reservoir site. We had so much leeway that you could not get down to the bottom.

Q. During those low day flows, you would take what percentage of the flow of the river? A. On those particular low days?

Q. On these July days which averaged, I think you said 650,000,000 gallons, didn't you? A. Yes—about 30 percent.

Q. About 30 percent would be diverted from this interstate stream? That is the amount? A. Yes.

Q. It was agreed, I believe, that the diversion from the Connecticut River, of the Ware and Swift project, averaged for the year two percent, wasn't it? A. Averaged for the year, yes. You are not comparing that with the low flow, with the lowest record in 40 or 50 years?

Q. No; I am not. A. I just wanted to be sure.

Q. The diversion on the Connecticut River was two percent, (1343) average for the year? A. For the years, based on average, not on any particular year.

Q. Of the average flow of each year the diversion was two percent? A. The average flow of all the years was two percent.

Q. In the period of low flow of the Connecticut River, the so-called diversion, under the restrictions of the War Department, would result in an actual addition, would it not? A. Yes, sir.

Q. To the Connecticut River? A. Yes, sir.

Q. If the Ware River project had been in operation in this month of July, 1911, and if your project had been in operation on the Merrimac, the comparison would have been that 30 per cent of the flow of the Merrimac would have been diverted and some addition to the flow of the Connecticut would have been con-

tributed? Is that right? A. I believe that is a fair statement.

Q. What consideration did you give, in planning this project, to the fact that the Merrimac River was in part navigable? A. I did not go into it.

(1344) that the Merrimac River below the point of diversion lies entirely in the State of Massachusetts; that it is entirely within the Commonwealth from Tyng's Island to the sea; that he considered also the fact that the river lay mostly north of the Massachusetts State line; that he saw no objection in that fact to using the Merrimac River as a water supply, any more than to the use of the Ohio by the cities in Ohio, considering that the watershed above those cites is almost entirely in Pennsylvania, or to the use of the Beaver River for water supply in Pennsylvania when certain branches of this river are almost entirely in Ohio; that he does not see where that had any effect; that he does not consider that the pollution of the Merrimac River, north of the State boundary line, was beyond the control of the State of Massachusetts; that at least one-third of the pollution above Tyng's Island came from Massachusetts and probably if Massachusetts adopted a conservation policy of cleaning up its streams the other states would follow in line; (1345) that regardless of that, a storage reservoir would so completely eliminate any question of doubt in regard to the use of this river that he did not consider it further; that he does not think it will be long before Springfield, Massachusetts, will clean up its sewage mess; that as far as pollution on the Connecticut River is concerned the river would be greatly benefited by cleaning up the pollution above the Massachusetts-Connecticut State Line; that he did not investigate the sources of the water of the Merrimac River in New Hampshire; that he did not go up to Winnepesaukee, Squam or Merrymeeting Lakes; that he did not go above Manchester; (1346) that he did not examine the legislation of New Hampshire regarding the regulation of the flow of these lakes; that he knows nothing about those lakes or the legislation respecting them; nor the acquiescence of Massachusetts in

that legislation; (1348) that if the War Department were to apply the same requirements to the Merrimac that were applied in the case of the Swift River, that is, a minimum flow of six tenths of a cubic foot per second per square mile of watershed, there would be no diversion permitted when the flow was less than 1,500 million gallons per day on the Merrimac River;

> (1349) (By Mr. Warren) Q. If the War Department adopted the same standard as on the Connecticut, would that mean that the War Department would not permit any diversion or might it mean that the War Department would not permit any diversion when the flow of the river was less than 1,500,000,000 gallons a a day? A. If there was navigation down there that justified it, that is what it would mean.
>
> Q. And if it did mean that, how long a period in that year of 1911 would we be unable to draw our 200,000,000 gallons a day when we needed it? A. I don't know.
>
> Q. From the Merrimac? A. I don't know.
>
> Q. You haven't the flow data to answer that? A. No, not here.

(1350) that if the Ware River rule were applied to the Merrimac River there would be four months in which no water could be taken; that the Army Engineers did not say that no water could be taken out of the Connecticut River during these four months; that he does not think they would apply the same rule on the main stream as they did on a tributary; that he does not think they would apply these rules to the Merrimac River at all; that the question of the effect of diversion on navigation on the Merrimac River was raised in connection with his investigation, but the only navigation on the Merrimac River was tidal, practically deep water navigation at the mouth; (1351) that he personally decided that navigation had no bearing on the question of diversion of water from the Merrimac River for the Metropolitan District; that he had given no consideration to the effect of the proposed diversion on dilution of industrial and domestic wastes in the Merrimac River below Lowell from a diversion of 30 per cent of the flow of the Merri-

mac River; that he made no investigation of what the nature of those wastes were nor as to how much water ought to be required to dilute them or make them less offensive; that he had seen the report of the Massachusetts State Board of Health in which it had been recommended that either these wastes be taken into a long intercepting sewer, or some method of purification or disposal resorted to; (1352) that he thinks that individual treatment plants for these wastes are more desirable than an intercepting sewer carrying the wastes out to sea; that the communities along the Merrimac River ought to take care of their wastes; that if 30 per cent of the available water at the most critical period should be diverted it would be increasingly important to take care of these wastes; (1353) that these disposal plants were necessary whether the Metropolitan District diverted water from the Merrimac River or not, according to the report of the Massachusetts State Department of Health; that according to this report, they were indispensable; that they had not been built; that if they were built as a result of diverting 30 per cent of the dilution water, they might have to be paid for by the Metropolitan District; (1357) that he had made no study of the growth of population in the Merrimac River watershed, nor any comparison between the population of that watershed and the population of the Ware-Swift watersheds; (1358) that he estimates the population equivalent, both actual population and industrial waste equivalent, above Tyng's Island on the Merrimac River at something like 400,000 or 425,000; that other things being equal, he would prefer to take a water supply from a watershed with a population of 37 per square mile, rather than from a watershed with a population of 88 per square mile; that other things again being equal, he would prefer to take a less rather than a more polluted water initially; that if he were consulted as to the source from which to take a water supply, the opinion of the public that was to use the water supply ought to be considered; that, assuming that two sources are available, it may be that public opinion would be the controlling element; that a condition cannot be assumed without knowing all the facts;

that the watershed that showed the lowest percentage of population growth per square mile would probably be preferable to the watershed that showed the greatest percentage of growth per square mile; that the weight which he would give to public opinion in the selection of a source of water supply would depend upon an evaluation of the circumstances which might arise in any individual case; that where everything else was equal, public opinion might be a controlling consideration; that he thinks the quality of the water would probably have a great deal to do with such an evaluation; (1360) that he would give weight to the fact that one water could be brought to its destination by gravity and another would require pumping at two different points in its progress only as this factor affected the cost; (1361) that Morris Knowles Incorporated designed and supervised the construction of the addition to the filter plant at Lawrence, Mass., in 1925; (1362-1363) that prior to this time, in 1917, in a report on sources of water supply for Lawrence to the Lawrence Water Supply Commission, Mr. Knowles recommended that the City obtain a supply elsewhere than from the Merrimac River; (1364) that in the plans for diverting water from the Assabet River, he investigated the use of water in the Assabet Valley for process purposes, and decided that rather than include in the plan a compensating reservoir, he would allow a certain amount to go down the stream past his storage dams similar to the amount of water that is allowed to go down the streams past the Wachusett and Sudbury Dams; (1365) that the quantity of water to pass the dams is 3 million gallons per day on the Assabet River; that this would be the average amount of water that would be let down; that he did not go into the element of the particular time in which this amount of water would be released; (1372-1373) that he examined the bottom soil of both the Foster-Martin reservoir and that on the Ipswich River at Willowdale but made no borings; that in both cases in general that this was sandy soil; that there was considerable muck on the Foster-Martin reservoir site which he planned to leave in place, except where located beneath the embankments; that

he made no particular investigation of the bottom soil of the Ipswich River reservoir except at the dam site; (1553-1565) that Exhibit C-34, prepared under Dr. Rudolfs' direction, shows in diagrammatic form the equivalent population of the domestic sewage and industrial wastes entering the Merrimac River and its principal tributaries from the Contoocook River above Concord, New Hampshire, to Tyng's Island in Massachusetts as determined by him in a field survey in 1929; (2212) that during the four summer months, July, August, September and October, of the extreme dry year 1880, the natural flow of the Assabet River was 1,690 million gallons; that of this flow 827 million gallons would have been the natural flow from 56 square miles which would not have been affected in any way by the diversions so that the water which would have been diverted, had no water passed the dams during this extreme low period, would have been the difference or 863 million gallons; that he has explained that a release from the dam is contemplated in the amount of an average of 3 million gallons per day throughout the year, or 1,095 million gallons per year and if this amount had been released during these four summer months, there would have resulted an actual increase in flow of something like 10 per cent; that he had testified that the average release would be equal to 3 million gallons per day throughout the year and that this dry weather release could be distributed in larger amounts during the dry time and in lesser amounts during the wet periods of the year; that the same type of release was suggested not only for the Assabet but also on the other projects such as the Ipswich and the Shawsheen; that, for example, there were 3 million gallons per day computed as release required on the Shawsheen River which could be described as desired safe regulation and is at least as much as Mr. Eddy testified was required by the large plant of the American Woolen Mills at Shawsheen Village; (2213) that with respect to navigation on the Merrimac River, recommendations have been made in Document No. 2 of the 61st Congress for increasing this depth to as much as 18 feet; that the channel was to be constructed by means

of locks and dams so that the diversion of water above would not in any way affect the carrying out of this project; (2214) that figures shown in Government reports upon the navigability of the Merrimac River indicate that the amount of water required for the operation of the project proposed, was only 85 cubic feet per second; that if the entire project were carried out and 310 cubic feet per second diverted (200 millions per day) there would be no effect on navigation by such diversion; that the proposed project does not depend at all upon any flow of water in the Merrimac River with the exception of 85 cubic feet per second for lockage; that if the Foster-Martin Reservoir were drawn down so that it contained only 10 billion gallons, there would be no swamp land exposed within the reservoir area; that when it was thus drawn down the minimum depth over the area of swamp material would be 18 feet of water; (2216) that the testimony of Mr. Uhl was based primarily on the assumption that water was to be diverted in the amount of 200 million gallons every day; that Mr. Uhl assumed that any loss over 2,250 cubic feet per second is a loss of primary power, and yet the records show that the flow at Lawrence for the whole month of July 1911 is only 1,190 cubic feet per second and that would be equivalent to only 1,060 cubic feet per second at Lowell; that therefore the limit at which the diverting of water from the Merrimac River would really have affected the primary power is less than half the amount which has been stated, so that most of the power loss would be loss of surplus power; (2219) that the installed steam horsepower at Lawrence in 1918 was 75,380 horsepower against installed water power capacity of 25,535 horsepower, and at Lowell it was 25,000 horsepower steam units as against 29,943 horsepower water units; (2220) that Mr. Uhl's calculations of power damages were based on the assumption that the diversion would be 200 million gallons per day beginning at the present time, whereas the fact is that the plan contemplates a gradually increasing taking of water from the Merrimac River only reaching 200 million gallons per day in 1970, and on this basis Mr. Uhl's calculation should be on the present

worth of the damage which is to be expected and that this amounts to $850,000 which compares with his (Mr. Jacobs') figures of $1,000,000 for the damages; that another check on that would be the estimated figure of the Army Engineers who stated that the loss in the driest years would only amount to $3,000 with the diversion of 85 cubic feet per second, based on Lawrence where the head was only 28 feet; that at Lowell the head is 36 feet so that on the same basis that loss would be about $3,900, or a total for the two powers in the dr[illegible]st year of $6,900; that if 310 cubic feet per second were diverted instead of 85, it would increase it to $25,000, which capitalized at 5 per cent would be $500,000; that that was a pre-war price so that it might be doubled to give $1,000,000; that present power costs are not double pre-war prices; (2223) that excerpts of the report to the Lawrence Water Supply Commission of 1917 by Morris Knowles Incorporated show that one of the advantages of the site finally recommended for Lawrence water supply was that Merrimac River water could be pumped into it and stored in the recommended reservoir on Bartlett Brook; that some of the other excerpts show the prejudices and the inefficiencies which existed in Lawrence, all of which he feels have been corrected by the project as outlined for a much larger district than the small city of Lawrence; that in spite of the fact that this report was made 13 years ago and other reports have been made since, Lawrence still takes its water out of the Merrimac River and the filtration plant has been improved; that he does not think that Lawrence objects to the use of the Merrimac River water; (2227) that one of the first projects considered in connection with the Foster-Martin Reservoir was an alternate comprising two reservoirs, but after the discovery of the reservoir site giving a capacity of 18 billion gallons, it was felt that there was ample protection in this capacity, particularly with the inclusion in the plan of a baffle dike to which this site readily lent itself; that the glue plant, whose wastes have a population equivalent of 114,000 persons, testified to by Mr. Eddy, is located on the Allegheny River less than 15 miles above the intake of the City of Pittsburgh Water Works; that the only way to get anything

worth while, in the way of a navigation project, between Haverhill and the sea on the Merrimac River, is the plan as recommended for the construction of locks and dams; (2233) that the flow now of the Merrimac River is so affected by the manipulation of the power dams, that the Army Engineers did not consider anything other than a slack-water navigation

> "similar to what we are familiar with on our inland rivers—similar to the operation on the Ohio, for instance, the Mississippi and the Monongahela and the other rivers"; (2246-2248)

that the storage capacity of his nine proposed reservoirs on the Assabet River would be 2,564,000,000 gallons; (2248) that the proposed release in dry weather from these reservoirs would be equivalent to 3,000,000 gallons per day or 1,095,000,000 gallons a year; that this release could be distributed in any way desired; that there is (2249) plenty of storage there;

> Q. Yes, but does your plan contemplate that amount of storage all the time in those little reservoirs? A. I didn't go into the details of how it would be operated.
>
> Q. Well, I am asking you whether your plan contemplated that amount of storage in those reservoirs? A. 2,564,000,000 gallons.
>
> Q. So that it would be available, there, to let down? A. Yes, sir.
>
> Q. Independently of what was diverted for use by the Metropolitan District? A. Oh, no.
>
> Q. Well, what do you mean by no,—that it would not be there? A. You would have 2,564,000,000, but you are not going to use that for stream regulation, you are going to use most of that for water supply.
>
> Q. And the balance for stream regulation? A. Yes.
>
> Q. And there would be enough—there would be that amount, you stated, of 1,095,000,000 left for stream regulation? A. Well, it would not have to all come from storage. You could use the dry weather flow to supplement it.
>
> Q. And did you make any calculations of what the dry weather flow was in the river? A. No, I accepted Mr. Goodnough's calculation.
>
> Q. Of those branches? A. Yes.
>
> Q. The little branches? A. Yes.

DR. WILLEM RUDOLFS, an expert witness for Connecticut, testified (470) that the Connecticut River, if judged by water supply standards, would need considerable treatment before the water could be used; (1100) that he made studies as to the quality of the water in the Merrimac River; that it is a good water for potential water supply with treatment as proposed by Mr. Jacobs; that a polluted water can be treated so that it is potable when there is no storage capacity available, by the use of chemicals, filtering and, as a safeguard, chlorination; that if possibilities of storage for a number of days, say 30 or more, are available, the stored water can be treated with chemicals in order to remove suspended and other material, bacteria included, filtered and then chlorinated; (1101) that he doesn't see that any better water supply can be obtained; that storage causes a reduction in bacteria, turbidity or suspended material, and color; that coagulation is the addition of chemicals to cause the material in suspension and part of that in solution to floc out or to form a floc; that the floc is then filtered out on the sand filter Mr. Jacobs described, and the impurities are taken out; that a rapid sand filter is nothing but a screening device holding back the material to be removed; that when a reservoir turns over, an unpleasant, disagreeable taste, sometimes even odors, result; that if water is sprayed into the air it comes into contact with the oxygen in the air and some of the oxidizable material will be oxidized and some of the gases which caused the odor will be driven out; (1102) that in some instances aeration is used after filtering to reduce the aggressive acidity or the corrosiveness of the water; that Boston at present relies upon storage; that campers in the woods might easily contaminate a storage reservoir; that storage has the object of reducing the number of bacteria; that this reduction in thirty days or more is at least 98 percent; that he has conducted experiments and finds that sewage, when stored for 13 days, has a reduction in bacterial content of 95 percent, and after 51 days, of 99 percent; that Sir Alexander Houston, of the London Metropolitan Water Board, states that a month's storage suffices

to kill harmful bacteria; that he thinks that Sir Alexander Houston is correct, at least for 99 percent; that other people have made similar experiments and obtained similar results; (1103) that when small particles settle out of water in storage they have a tendency to carry some of the color with them; and that there is a bleaching effect of sunlight; (1104) that the effect of storage is to decrease turbidity; that the turbidity in the Merrimac is very slight, about one part per million; that one type of industrial waste can be classified as material, either organic or inorganic, capable of settling; that this material would settle out and go to the bottom; that another type of industrial waste can be classified as material in solution; that as in the reduction of color, this material would be removed by settling particles; that some of the material in solution is oxidized and changed so that it is not harmful and produces no nuisances; (1105) that the Boston water supply, as he understands it, has chlorination only as a standby, and relies entirely upon storage; that no modern engineer would rely upon storage only unless he had storage of several years; that practically all surface water, including rivers, creeks and ponds, is somewhat polluted; that if he had storage of a year or two, he would still chlorinate; (1106) that the bacterium coli index of the Merrimac River in 1928 was 4200 in 100 cubic centimeters of water at the Lawrence intake; that storage for 30 days or more would reduce this number by 98 percent, leaving 84; that coagulation and filtration would remove 99 percent of the remainder, leaving 0.84 B. Coli per 100 cubic centimeters, which is below the Treasury standard; (1107) that the Treasury standard is 1 B. Coli in 100 cubic centimeters of water; (1108) that chlorination is mixing a certain quantity of liquid chlorine with the water; that chlorine is a strong antiseptic and will kill any bacteria that might have escaped all other treatment; that you would not get the some result with chlorination if you left out all other processes, as the chlorine would not penetrate into the small particles in suspension and kill the organisms; that if the water had been stored and 99 or 99½ percent of the bacteria removed, chlorination is satis-

factory; (1109) that the Wachusett Reservoir should be chlorinated as a safeguard; (1110) that starting out with a B. Coli index of 4200, removing 98 percent, there are 84 left, which might be enough to cause an epidemic; that he did not analyze Wachusett water; that with modern plants, the human element is very small indeed; (1111) that with the treatment processes described, there is a series of safeguards; that by the time water is treated with all the processes there is a much better chance for satisfactory water than if reliance is on only one safeguard; that of all the treatment processes, storage is not the most effective; there are many towns that must rely on filtration to get a good pure and safe water; (1112) that he can think of no large city in the United States, outside of Massachusetts, that doesn't chlorinate its water; that chlorination is a standard practice; (1113) that if the Merrimac supply, after being treated by all the processes described, were chlorinated properly, it would have no taste from the process; that color in most rivers is caused by decayed roots and leaves, brownish material, showing in solution; that experiments were made on samples of Merrimac River water with colors of 35 to 43 parts per million by adding a certain quantity of alum which resulted in a reduction of color to 7 parts per million, which is under the Treasury Department standard; (1114) that the Treasury Department standard was 10; that the turbidity of the Merrimac River water was very low and would be reduced by coagulation and filtration still further; that if alum is added to water, the alum being acid would cause the water to become acid and attack the pipes; that in order to neutralize this acidity, lime is added to get a water that is perfectly safe; (1115) that aeration was recommended for the Merrimac project to remove taste and odor-producing gases; that if the Merrimac River water was stored and treated as described by Mr. Jacobs, the treated water would be safe and pure, and equal to or better than the present Boston water supply; that the Merrimac water stored and treated would be as good or better than the proposed Ware-Swift supply; (1116-a) that if the Ware-Swift supply was not chlorinated, the Merrimac water would be

safer; that any of the supplies when treated such as the Assabet, Sudbury and Ipswich, would be equal to or better than the present Boston water supply, and better than the proposed Ware and Swift supplies without chlorination; (1118) that if cost were no consideration, he would prefer the less polluted of two sources of water supply; that the Ware and Swift waters initially are better than the Merrimac water; (1119) that if cost and legality and things of that sort are not considered, the Ware and Swift are to be preferred to the Merrimac; (1120) that in recommending a source of supply for the city, cost usually goes first and then convenience; that as regards unity of sources, he would prefer the Ware and Swift supplies to supplies having sixteen watersheds and would prefer the Merrimac supply to the Ware and Swift supplies; (1124) that raw water stored improves in quality, in freedom from bacteria, in reduction of color and turbidity, and in oxidizable material; that if a reservoir for storing water after filtration were well protected from pollution, whether or not the water was stored would make little difference; that if cost were not a consideration, such a storage reservoir should be covered; (1125) that he knows of open and of covered reservoirs; (1127) that since plankton and small animals and plants depend for their subsistence on food supply and the food supply has been removed by filtering, they would not grow much faster since microscopic growth depends mostly on the food supply; (1128) that he believes that the covering of distribution reservoirs might be more to prevent subsequent pollution than to keep the light out; (1129) that the covering of filtered water reservoirs was an historical outcome of the manner of building reservoirs; (1131) that he agrees with Mr. Hazen that stored water might have some growth but not because it is filtered; (2250) that investigations were made of pollution in the Merrimac River, starting July 12, 1929, and ending October 31, taking samples every day at Tyng's Island, for dissolved oxygen and biochemical oxygen demand; that the average for that period of 111 days was 6.54 parts per million of dissolved oxygen,

or 70 percent of saturation, (2251) and 1.9 parts per million biochemical oxygen demand; that the average stream flow for that period was 1518 cubic feet per second, as given to him by the Engineers, and the temperature averaged 18.8° Centigrade; that the Merrimac River at Tyng's Island is 40 percent better than the Connecticut River at the Massachusetts-Connecticut State Line, as far as dissolved oxygen is concerned, and (2250) 24 percent better as regards biochemical oxygen demand; (2253) that the usual practice of removing corrosive agents from water was by applying lime or, in some instances, by aeration; that peat is a material that decomposes slowly and that it would furnish food for microorganisms in water supply reservoirs, increasing the growth of algæ and necessitating the application of copper sulphate once or twice a year in order to overcome the growths; that the methods used in a few instances for treating water containing phenol and paper waste, known as lignine, is by activated carbons; (2254) that waste phenol in the amount of 10,000 tons a year is dumped into the Emscher River in the Emscher district in Germany in addition to the sewage and other things that go in; that water from the Emscher seeps through the soil and still contains some phenol; that it is then filtered through carbon and the taste is removed; that there have been experiments in this country and some plants are being built to do the same thing; (2255) that the taste at Lawrence only occurs in that part of the city where the water is put directly in the mains after it has been filtered; that after the water has been stored, there is no taste; that the reason is that bacterial action takes place and the phenols break down rapidly; that experiments have shown that 50 to 60 percent of the phenols break down in three or four days and all of the phenols have disappeared in twelve days, by bacterial action in storage; that water is not manufactured, but purified.

MAJOR EZRA B. WHITMAN, an expert witness for Connecticut testified ((1158) that he had made an investigation as to the water supplies available for the Metropolitan District in Eastern Massachusetts; (1161) that he thought the storage of Merrimac River water as proposed for 90 days will eliminate practically all objections to the use of that source; that in the studies that were made by the Massachusetts State Board of Health on the Merrimac River, he does not recall that there was any study as to the storage of the water previous to filtration; that with the stored water from the Merrimac followed by filtration and chlorination, there would result one of the best water supplies in the United States; (1164) that in practically all the different places where he has been called in as a consulting engineer to advise the city as to its water supply, the question of cost was a dominating and determining factor; (1166) that the Fifteen Watershed Plan is the kind of development being made every day; (1167) that the drainage area of the Ipswich River at Willowdale Dam is 121 square miles and the available drainage area from Wachusett, 108 square miles;

> (1172) Q. (By Mr. Warren) Mr. Whitman, are you now in charge of the Albany Water Works Department? A. Yes, my firm is.
>
> Q. Yes. Well, were you consulted before it was undertaken? (1173) A. No. I was in very much the same situation that Mr. Winsor is in the Boston situation. They had selected—although we did help them to select the particular project.
>
> Q. You did help them to select . . . A. Yes.
>
> Q. Including the source? A. Including the source.
>
> Q. Of supply? A. Yes.
>
> Q. What is that source of supply? A. The source of supply is from what they call the Hannacrois-Basic Creek supply; that goes to the Catskill foothills, and we take two streams—water from two streams, the Hannacrois Creek and Basic Creek.
>
> Q. In the foothills of the Catskills? A. In the foothills of the Catskills.
>
> Q. They are south of Albany, aren't they? A. Yes, a little south-west of Albany.

Q. A little south? And how do you take the water to Albany? By pumps? A. No, take it by gravity.

Q. Gravity? A. Yes.

Q. Where did Albany get its water before? A. Got its water from the Hudson River.

Q. That was an ample supply, wasn't it? A. Yes, very ample supply.

Q. Plenty of water? A. Plenty of water.

Q. Did you recommend that they continue to get it from the Hudson? A. No, I would not have recommended that they continue to get it from the Hudson.

Q. You would not? A. No.

Q. They had their works more or less established at the time, didn't they? A. Yes.

Q. What was the matter with the water? A. The trouble with (1174) the water in Albany was that, with the growing industrial communities from Schenectady practically right down to Albany, and with the sewage going in just within a few thousand feet of the intake and with the pulp—

Q. You mean above or below it? A. above it.

Q. Yes. A. The sewage going in right above it, so that there was practically fresh sewage going into the intake; with the *pulp paper mills—pulp mills coming down and interfering very largely with the filtration processes;* also with the filtration plant where it was in danger of being flooded out by high water, as once happened from the Hudson, and with the water in such a condition that it was a tremendously expensive water to handle, that is to filter, it costs probably three or four times as much to filter the water in Albany as it would in an ordinary city.

Q. Where is the intake with respect to Albany? A. It was just at the north end of Albany. But the whole shore practically up to Troy is more or less built up with practically solid towns.

Q. Well, I am familiar with the river, just as I am with the Merrimac. A. Yes.

Q. Of course if that water had been stored, 98 per cent of those impurities would have disappeared in 60 to 90 days? A. Yes.

Q. And if it had been filtered there would have been less than one per cent left, wouldn't there? A. Yes.

Q. And the chlorination would have absolutely wiped that out, wouldn't it? A. That is correct.

Q. And the city would have saved all of the expense of going to the foothills of the Catskills? A. Oh, no, no, you haven't (1175) let me finish my story, Mr. Warren, in connection. The cost of filtering is very high. Also every drop of water has to be pumped.

Q. How many drops of the Merrimac would not have to be pumped to the city of Boston? A. It would all have to be pumped.

Q. Every drop? A. Every drop, but when we did this—

Q. How many times did you pump it, under that scheme? A. How many times did we pump it?

Q. The Merrimac water, yes. A. Twice.

Q. Twice, A. Yes. Well, now, Mr. Warren, what actually happened from an economic point of view—point of view of economics, Mr. Nicholas S. Hill was called in to advise the city of Albany, first, and he did, as to whether to stay in the Hudson River or to go out of the Hudson River.

Q. Who is he? A. He is a consulting engineer of New York.

Q. Yes. A. He figured that by going to a supply such as we selected that you would save ten million—I think about ten million and a half dollars by capitalizing the cost of filtration and pumping and the reduced expenses that would come through this other source of supply. The actual expense on that proposition is about nine million dollars. So that your capitalized savings will pay for this new supply, to say nothing of getting a water supply that is very much safer where you have no chance of being flooded out with your filtration plan and the difficulties of that plant that it is not a plant that was built to handle such a water and they have . . .

Q. Which? The present? A. The present plant.

Q. The present Hudson plant? A. The present Hudson plant. There are plants that could be built, I think that could (1176) handle that water very much better than the existing plant that they have.

Q. Did you make any estimate on what such a plant would cost? A. Oh, I can tell you roughly what a plant of that kind would cost, probably around one million to a million and a quarter dollars.

Q. You mean a proper plant for the treatment of the Hudson? A. A proper plant, yes. I would not treat the

Hudson River because the water there is a very difficult water to treat. Some waters yield readily to treatment and others do not. Apparently it is the *pulp wastes* which interfere very considerably with the filtration process.

(1177) Q. Those are quite a distance up the river, are they not? A. Some distance up the river.

Q. Where are they,—up around Lake George, up in that vicinity? What is the name of the place there? A. They are up in the upper Hudson, up above.

Quite a good many miles above this intake, aren't they? A. Yes—I should say, judging from the records and the experience in the Merrimac River, that the Merrimac River is a very much easier water to handle than the Hudson River water is, considering the results that have been obtained in Albany. Those two plants were both built as slow sand filter plants. The Merrimac plant has kept on as a slow sand filter plant with no practical additions. The Albany plant was built as a slow sand filter plant. They added three filters to it. That didn't work. They have added aeration and they have added, in addition to that, coagulation, and they have kept adding to that plant, trying to make it work. It doesn't work—it has not worked satisfactorily.

Q. You were saying it has not worked satisfactorily? A. It has not worked satisfactorily, and the Merrimac River plant at Lawrence has worked satisfactorily, according to the best information which I can get.

Q. What do you say it would cost to put in a proper plant there? A. I wouldn't put in a proper plant there. I wouldn't attempt it.

Q. I thought you said $1,000,000? A. I said a plant that would handle it better than the present plant could be built (1178) for a million or a million and a quarter, but I would not attempt to handle it at that point.

Q. As long as you could get it from a mountain stream at the foot of the Catskills you would prefer to go there? A. Particularly as you would pay the interest on the cost of developing that mountain source by the savings in filtration cost and pumping cost.

Q. You would not filter this water from the foothills of the Catskills? A. Yes, we do.

Q. Your filtration plant would not cost as much? A. Your filtration plant would not cost as much and it would not be as difficult to operate.

Q. Why wouldn't it cost as much? A. You mean the plant itself?

Q. Yes. A. I was thinking of the filtration.

Q. I am speaking of the filtration? A. The process of filtration. You wouldn't need to use, probably, more than half or quarter the amount of chemicals that you use in treating the Hudson River water, and your chemicals in the filtration process are the large element of cost.

Q. You mean the alum and the lime? A. They use on an average four grains of alum to the gallon in treating the Albany water supply. The usual amount that you use is about a grain to a gallon.

Q. Why wouldn't you have to use as much on this water from the Catskills? A. Because the water hasn't the chemical and the industrial wastes in it, of all kinds, such as come from those industrial cities all the way up the river to Schenectady.

(1179) Q. Is it because the water is less polluted? A. There are practically no industrial wastes at all in the supply that we get up there, while the industrial wastes in the present existing intake at Albany are very considerable.

Q. Are there also domestic wastes? A. Yes, there are domestic wastes too.

Q. And there are no domestic wastes to speak of in the Catskill waters? A. No. There are a few small communities up there

Q. In fact, I think you said it was as pure as the water of the Swift and the Ware? A. I think it would compare very favorably with them."

(1183) that he had made no investigation of the growth of population on the Merrimac River watershed; (1184) that he did not find in his studies that anyone had ever before recommended the Merrimac River as a source of water supply; that most of the contribution of waste to the Merrimac River is above the proposed intake.

WATER SUPPLY

DR. JOHN H. GREGORY, an expert witness for Connecticut, testified (1243) that he was one of a group of engineers asked to review the studies made by Morris Knowles Incorporated on the development of possible water supply projects in Eastern Massachusetts for the Boston Metropolitan District; (1245) that he is in substantial accord as to the yield of the projects, and the cost and the practicability of them, as water supply sources, with Mr. Jacobs; (1245) that he considers the Merrimac River development practical; that there is nothing unreasonable about it; that it is a reasonable development considering its cost; that the resultant quality of the water, if treated in accordance with the works proposed, that is, with the storage reservoir, aeration, rapid sand filtration and chlorination, is one of the highest quality, of fine appearance, sparkling, and perfectly safe for anybody to drink, and equal to the best supplies in the United States; that he has been connected with the construction of various supplies in the United States and has visited and inspected a great many other supplies with which he had no direct professional contact; (1246) that the supplies in other cities are comparable with the project on the Merrimac River; that there are many cities that are filtering polluted waters and that are producing fairly satisfactory water; that there are many large filtration plants in the United States of the rapid sand type and there are also plants of the slow sand type; that Washington, D. C. has both types; that Washington, D. C. has recently constructed a rapid sand filtration plant taking water from the Potomac River; that the City of Cleveland has two large rapid sand filtration plants; that the City of St. Louis has one large rapid sand filtration plant taking water from the Mississippi River and has now under construction a second large plant to take water from the Missouri River; that Detroit has the largest rapid sand filtration plant in the world; that this plant takes water from the Detroit River; that New Orleans has a large rapid sand filtration plant, taking water

from the Mississippi River; that Cincinnati has a large rapid sand filtration plant taking water from the Ohio River. Louisville the same way; that Columbus has a rapid sand filtration plant, taking water from the Scioto River; (1247) that some of the raw waters that these cities are using are polluted to a lesser degree and some to a higher degree than the Merrimac River; that there are also many smaller cities that are treating water with rapid sand filter plants; that the degree of pollution of the raw water in the Merrimac River is not so large that it is impracticable by filtration processes to make it suitable as a potable water; that the places that he has mentioned depend largely upon filtration and chlorination for the treatment of water; that in the case of Cincinnati they have two preliminary settling reservoirs which afford some eight days' storage, but most of the plants are taking the water direct from the river, treating it with coagulants and passing it through mixing chambers, settling tanks, rapid sand filters, and finally chlorinating; that it is a well known, almost standard method of water purification; that the rapid sand filter today in the United States is more widely used than any other type of water purification works; (1248) that the storage provision at the Foster-Martin Reservoir would very materially improve the quality of the water to be filtered; that the estimate of cost for the Merrimac River project was made on the basis of 200 million gallons per day yield for the water filtration plant, and there is very much more water available in the Merrimac River than that quantity; that 200 million gallons per day in the Merrimac River would not exhaust that supply; that the quality of the water treated as proposed from the Merrimac would be superior to the water delivered as proposed from the Ware-Swift project; (1250) that water after filtration should be stored in covered reservoirs; that the same thing applies to a surface water if it has been brought to a point in a distribution system where it is then to be distributed; that on the other hand, there are many examples of filtered waters which are kept in uncovered distribution reservoirs; for example, Albany, New York; Cincinnati, Ohio; Trenton, New Jersey;

part of Philadelphia; and Baltimore; (1251) that if the reservoir is not covered, and algae growths occur, the safety of the water for public consumption is not affected; that algae growths might result in an unpleasant taste and odor; that algae growths in reservoirs are controlled by the use of copper sulphate; (1253) that the development of the Fifteen Watershed Plan is entirely practicable; that it would give a water of excellent quality and better than the present water supplied to the Metropolitan District; (1256) that other things being equal, it is simpler to operate a works with a large unit like the Merrimac project than a number of small units like the Fifteen Watershed Plan, but as for the water, he thinks both of them, or either of them, will give a water of a high grade, meeting the requirements of the United States Treasury standards; (1259) that irrespective of whether the water came from the Merrimac and is filtered, or whether it came from the Ware and Swift, when it has been brought to the point where it goes into the distribution system if it is necessary to protect the quality, the reservoir in which it is stored should be covered; (1260) that there is much more water in the Merrimac River than 200 million gallons per day; that the volume that can be taken from the Merrimac is not limited by a statement made on the basis of estimates of 200 million gallons per day; that the water of the Merrimac River if treated as proposed will give a thoroughly high grade of satisfactory water that will fully meet the requirements of the United States Treasury standard and will be a better water than the water brought from the Ware and the Swift down through the Wachusett system and delivered to the Metropolitan District; (1263) that all of the water in the Ware and Swift Rivers can be fully developed with a storage of between 134 and 140 billion gallons; that he cannot see why such a large reservoir of between 300 billion gallons and 400 billion gallons, as proposed by Massachusetts, would be needed when a considerably smaller one would serve to take all of the water; (1266-1267) that from an engineering point of view, assuming that by 1970 or before, the Metropolitan District demand for water has

approached the safe yield of all sources and the Swift River reservoir has been built, the logical place to get more water is from the watersheds in the vicinity of the Swift River reservoir so that Swift River reservoir storage would be utilized; (1268) that it would not be practical to take Eastern Massachusetts water supplies and pump them over to the Swift River reservoir; (1269) that future additions to the Ware-Swift project must come from other tributaries of the Connecticut River; (1271) that there is something like 35 million gallons per day available from Assabet River tributaries, which on the basis of per capita consumption of say 110 gallons per day, would supply a population of nearly 320,000 persons, and if Boston today has a population of perhaps 900,000, the water from the Assabet is sufficient to furnish one-third of the water supply for the city of Boston; (1272) that the Whitehall Reservoir in the so-called South Sudbury watershed of the present Metropolitan District sources has a small watershed, Ashland has a small watershed, Hopkinton has a small watershed, and if you take the present sources of supply of the Metropolitan District, there is Wachusett, Sudbury No. 5, Framingham No. 3, Framingham No. 2, Framingham No. 1, Ashland, Hopkinton, Whitehall and Cochituate, which make nine sources of supply that have to be handled at the present time; that he sees no difficulty in handling these nine, nor does he see any difficulty in handling the nine smaller ones on the Assabet River; (1272-1276) that the nine sources of supply which constitute a portion of the present Metropolitan District sources did not constitute a system laid out and constructed at one time, but a system developed by addition of one and then another to an existing system; (1278) that the present Boston system of delivery to distribution system is by gravity; (1294) that he did not consider the substitution of a single dam on the main Assabet River in place of individual dams on nine tributaries because the Assabet Valley has the Boston and Maine Railroad running through the heart of it and it has the cities of Hudson and Maynard, and it did not look desirable; (1225) that if a single dam were built on

the main stream of the Assabet River, it would be necessary to pump all of the water into the Wachusett Aqueduct; (1299) that there is probably some process water required in the industrial establishments in Maynard and Hudson on the Assabet River; that the development of the reservoirs as proposed would cut off a certain amount of the flow of the Assabet River and still leave a considerable area of the Assabet River that would not be cut off; that he had not figured what percentage of the total flow of the Assabet would be cut off; that the reduction in the flow would be felt most in the dry period; (1300) that no borings were made at the site of the proposed Ipswich river dam at Newburyport turnpike; that there would be no difficulty in building a reservoir at the proposed Willowdale site on the Ipswich River; (1302) that if he were consulted by the Metropolitan District as to going to the Merrimac River or as to going to the Ware and Swift Rivers for approximately the same amount of water, assuming that the cost would be approximately the same, or that the client did not care about any difference in cost, he would take the Ware and the Swift as the lesser polluted streams; (1303) that there is an advantage in having an entirely independent source of supply coming into the District from an entirely different direction; (1304) that the question of pumping water is a very simple thing; (1305) that in considering a source of water supply, he would take into consideration the population on the watershed, but with adequate treatment it would not be much of a factor; (1306) that from his visit to the two watersheds, there is less density of population on the Ware and Swift Rivers than on the Merrimac River; (1308) that the preference of the public as to a water supply is a sentimental factor that sometimes has to be considered if the question of cost is eliminated; (1310) that the opinion of the public which is to use a water supply is a factor to be considered by engineers in determining the source from which the water will be taken; (1314) that if gas house wastes (the phenols) are present to a material extent and chlorine is added it will probably intensify the taste; (1315) that there have been troubles

at times in the Ohio River but the manufacturers have now largely taken out the phenols by treatment at the works; that judging from the experience of Lawrence with chlorinating the Lawrence filtered water, he hasn't known that the phenols were a factor; that in the past there has been some feeling in Lawrence against the Merrimac river water; that he understands that it has died down at present; (1316) that the Massachusetts State Board of Health have not been in favor of filtering Merrimac river water; that they say it can be done; that he knows of no instance in which any commission or state board of engineers, prior to this case, has recommended the use of the Merrimac river water even for communities along the Merrimac River in Massachusetts; that in general the larger part of the wastes which would be present in the water at Tyng's Island came from New Hampshire; that the fact that this waste came from New Hampshire might be a factor in determining on the source of water supply; (1322) that he gave no consideration to providing a compensating reservoir for maintaining the summer flows on the Assabet River above Hudson; (1326) that the increase or decrease in density of population on a watershed would be a factor to be considered in selecting a source of water supply; (1329) that he believes the proper method of treatment of the gas house and paper mill wastes would be sedimentation of some kind together with oxidation; that storage and aeration plus filtration would take care of the gas house and paper mill wastes on the Merrimac; that a water works engineer would prefer a few units to a multiplicity of small units; (1331) that he thinks the Merrimac River is a better source of water supply for the Metropolitan District than the Fifteen Watershed Project; that he did not determine how much water was available from the Merrimac River; (2192) that many large cities pump all of their water supply; that the question of the pumping lift for raw water has nothing to do with the situation if you are going to filter and purify water; (2194) that the effect of discharging sewage and industrial wastes into the Merrimac River and its tributaries can be judged by the analyses of

the quality of water at Tyng's Island; (2198) that the best way of judging the efficiency of water purification processes is by the reduction in typhoid fever death rates before and after filtration.

PROFESSOR CHARLES-E. A. WINSLOW, an expert witness for Connecticut, testified (509) that there are various standards by which one may judge a stream; that the Connecticut River is not suitable for drinking without treatment; that the standard for water for drinking is 1 colon bacillus in 100 cubic centimeters of water; that no surface stream meets such standard without treatment; that Connecticut River water could be used as a source of water supply if it were properly treated; that it is beyond the limit generally considered safe for treatment by filtration and chlorination alone; that it is regarded, according to generally accepted standards, as a water to be first stored, then filtered, and finally chlorinated; (510) that the cost of this treatment would be high; that the Public Health Service estimates that for every increase of 100 colon bacilli per cubic centimeter, the cost of treatment increases $10.00 per million gallons; that Connecticut River water was used by the City of Hartford for drinking 25 years ago, when, during the winter months, their reservoir froze up and they drew directly from the river; (511) that they suffered from typhoid as a result; (525) that the Connecticut River compares with other streams used or proposed to be used for water supply, as follows:

	Colon Bacilli per Cubic Centimeter
Mississippi above Minneapolis	13
Maumee at Toledo	20
Allegheny at Pittsburgh	21
Ohio at Louisville	22
Grand at Grand Rapids	26
Delaware at Trenton	29
Ohio at Cincinnati	30
Mississippi at St. Louis	31
Maiden Creek at Reading	42
Merrimac at Lawrence	42
Mahoning at Youngstown	54
Schuylkill at Philadelphia	59
Connecticut above Hartford	68
Missouri at Kansas City	159
Hudson at Albany	194
White River at Indianapolis	225
Connecticut at the State Line	378

(526) that he took the average for the Connecticut for July to November, 1928; that the Connecticut above Hartford is the best point on the river; (527) that his figures included only the true bacterium coli, whereas the other figures include the entire colon group which would tend to make them higher than his; (1135) that storage will effect a reduction of bacteria of all kinds that will grow on the jelly media commonly used of about 90 percent in a period of three or four weeks; that his figure will vary with the kind of bacteria concerned; (1136) that of colon bacilli placed in water, 78 percent survived one day, 49 percent three days, five percent five days, and one percent ten days; (1137) that with colon bacilli the rate of reduction is equivalent to about 2½ percent per hour of those alive at the beginning of the hour; that the rate of decrease remains constant but the actual decrease gets lower because the number that die in a given period is a percentage of those living at the beginning of the period; that another factor of importance is the action of other organisms in the water which destroy bacteria; that light and temperature also affect the process; that the main factor is that the intestinal

bacteria are in an unfavorable environment and die out because they cannot live and develop; (1138) that the time element is the controlling factor and is effective regardless of whether the water is at rest or in motion; that typhoid bacilli die out from 8 to 20 or 30 times as fast as colon bacilli, varying somewhat with the temperature; that Sir Alexander Houston in London found that, depending on the temperature, the typhoid bacilli die out in from one to, at the outside, eight weeks; (1139) that the higher the temperature the quicker the bacteria die out; (1141) that the proposed reservoir for the Merrimac River is so designed that it would give a 60-day storage to all water that goes through it; that sometimes short circuiting of water occurs; that the reservoir to be used in connection with the Merrimac supply provides a central dike to avoid such short-circuiting; that he is confident that the water will get at least 60 days' treatment, probably nearer 90; that this will effect a minimum purification of 98 percent; that assuming that the Merrimac River contains roughly 5,000 colon bacilli per 100 cubic centimeters, there will not be over 2 percent of that or 100 per hundred cubic centimeters leaving the reservoir; (1142) that he had studied the analyses of the Merrimac River as given by the Massachusetts State Board of Health and also, with regard to certain qualities of the water, the analyses of the United States Geological Survey; (1143) that according to all ordinary standards the water was suitable for treatment by chlorination and filtration so as to make it a source of potable water; that the water had a high bacterial content, a high color as compared with that desirable and too much iron for an ideal water; that all of these qualities can be easily handled by the type of treatment proposed; (1144) that there is no doubt this process will reduce the color of 40 down to a value of 10 or less; that he believes that filtration and chlorination alone would yield a satisfactory water; (1145) that Lawrence, where there is a less complete and effective filtration plant than here proposed, has obtained a water which, in at least one or two years, has been pronounced by the State Department of Health as better than that of the

Metropolitan District; that the typhoid rate in Lawrence has been one of the very low rates in the country; that the water is, he believes, considered suitable for treatment by filtration and chlorination, even without storage; that, however, it is desirable to add the additional safeguard of storing; that there are three general methods of treating water: storage, filtration and chlorination; that he believes that any two of those three in combination would make a satisfactory water; that he believes that the third should be added because even with the other two there is a possibility of some slip; (1146) that the water is not so seriously damaged by manufacturing wastes that there would be difficulty in treating it; that there are many cities in the United States and in Europe successfully treating water more polluted than the Merrimac by filtration and chlorination without storage; that he had prepared the following list of cities now treating water almost as polluted or more polluted than the Merrimac, as measured by colon bacilli:

	Colon Bacilli per 100 Cubic Centimeters	Colon Bacilli per cubic centimeter (Computed from evidence
Toledo	1980	20
Pittsburgh	2058	21
Louisville	2220	22
Grand Rapids	2563	26
Trenton	2891	29
Cincinnati	2980	30
St. Louis	3120	31
Lawrence	4200	42
Reading	4219	42
Youngstown	5450	55
Philadelphia	5899	59
Kansas City, Kansas	15892	159
Albany	19400	194
Indianapolis	22500	225

(1148) that none of these cities had any extensive storage; that he had divided the cities of the United States of over 100,000 population, according to their source of water,

and determined their typhoid death rates for the five years 1924 to 1928; (1149) that these groups, with their typhoid death rates per 100,000 were as follows:

7 cities having underground water supplies	6.4
20 cities which used a water supply of rather good quality without filtration including Boston, Bridgeport, Conn., New York and some cities using chlorination but not filtration	2.1
A third group of cities using treated water of fairly good initial quality by filtration	4.2
A fourth group treating river waters of very poor quality by filtration, including Albany, Indianapolis, Kansas City, Missouri, Philadelphia, Reading, St. Louis, Wilmington and Youngstown	3.0

that this computation is a little unfair because certain groups, particularly groups 1 and 3, have a number of southern cities in them which, on account of their negro population, have high typhoid rates; (1150) that the differences found obviously have no significance with regard to water supply; that these rates are so low that the conclusion is that there is no appreciable amount of typhoid due to the water in any of these groups; (1151) that starting with a water with a B. Coli index of 5,000 per 100 cubic centimeters and storing and filtering the water, the water will then have a B. Coli index of 1 per 100 cubic centimeters, which is the standard for good drinking water; that he believes it wise to chlorinate in addition; that chlorination would "catch the last one"; (1153) that he believes the soundest plan for the Metropolitan District is the development of the Merrimac River, but that the development of the small supplies is, from a health standpoint, entirely feasible and satisfactory; (1154) that there are three criteria of a satisfactory water supply: 1st, the water must be safe and unobjectionable from a standpoint of color, turbidity, taste, etc.,—2nd, there is the factor of economy,—and 3rd, there is the factor of water conservation policy; that he liked the Merrimac plan better than the smaller supplies because it is more compact and allows for possible expansion on a larger

scale; that the Merrimac supply developed as described would be very much better than the present water of the Metropolitan District; (1158) that the effect of storage on industrial wastes would be toward removal of the heavier suspended matter by sedimentation and the oxidizing of organic wastes of a decomposable or oxidizable nature into harmless forms so that most of the more important waste would be taken out by storage; (1450) that the Massachusetts State Board of Health is an unusually good one and far above the average; that he knew the late Commissioner Kelley very well and considered him a competent and efficient head of that Department; that he had confidence in his judgment; (1451) that between the Ware and Swift River supply and the Merrimac River supply, he would recommend the Merrimac for the Metropolitan District; that this decision was based upon three things: 1st, the quality of the final water which would be produced as regards color, odor, taste, etc.,—2nd, the cost,—and 3rd, the extent to which the given supply interferes with other communities within or without the state; that the initial purity of the water from these two sources would not weigh with him at all, if a water could be produced of the same or better purity at a lower cost; that leaving cost out of the question he would be willing to start with a considerably polluted water if the process was to yield a water of equal or better quality at the end; (1452) that as an expert he would not give any weight to prejudices or opinions of the consuming public in a community that was to be supplied; that if he were to have any political responsibility he might have to; (1453) that he had no doubt of the scientific possibilities of making a good water out of the Connecticut River; (1454) that with entirely satisfactory ultimate quality the only two questions of significance are the cost and the relation to the needs of other communities; that one community should not hog the water at the expense of another community; (1455) that taste, odor and hardness are important in water supply questions, coming under the heading of "Quality"; (1456) that except for hardness which affects the pocket-book, there is no reason to consider them

except that the public does not like them; that to his knowledge, there is no community taking water from the Connecticut River for a water supply, either in Massachusetts or Connecticut; (1457) that he knew of no community in Massachusetts that uses the Merrimac water except the City of Lawrence; that he was familiar with Mr. Knowles' report to the Water Commission of Lawrence in which abandoning the Merrimac water was recommended; that this report was influenced mainly by public opinion; that according to the report the Merrimac water could be made satisfactory;

Q. Have you ever seen or heard of a reply by the State Department of Public Health of Massachusetts to the City Council of Lawrence, answering certain questions, and dated April 15, 1922. A. I don't remember that.

Q. Supposing that there was such a report—response, rather—And that question was submitted to the State Board of Health, as follows: "Is it advisable, from a viewpoint of safety and precaution, that the city of Lawrence seek a new water supply and, if your opinion is in the affirmative, what considerations make it advisable?" (1458) And supposing that the response of the Department was as follows: "The Department in answer to this question has carefully considered the history of the present water supply of the city of Lawrence since it was first installed nearly fifty years ago. When introduced in 1873 the supply was taken in part from a filter gallery near the river and in part from the river itself. In time very little water was obtained from the filter gallery and the chief source was the Merrimack River, from which the water was drawn directly into the supply pipes of the city. For many years the city had a high death rate from typhoid fever. This matter was the subject of careful study by the State Board of Health after its appointment in 1886, and the source of this typhoid fever infection was traced by the late Hiram F. Mills, C. E., member of the Board, to the use of the polluted water of the Merrimack River for the water supply of the city. Studies of methods of purifying the water were begun at the Lawrence Experiment Station in 1887, and as soon as the cause

of the excessive prevalence of typhoid fever in the city was ascertained to be due to the river water, the Board recommended that the water be purified by filtration through sand. While there was much skepticism at that time as to the danger involved in using unpurified river water for drinking, the filter was nevertheless finally installed with results that greatly exceeded expectations in its improvement of the health of the city. The filter was built after the least expensive design that it was practicable to devise, and after it had demonstrated its efficiency the city was later on urged to replace it with a more effective structure.

"The history of filtration in Lawrence following the introduction of the filter and the realization of the fact that it had effected an enormous improvement in the health of the city seems a fair basis on which to judge the probable future experience in the continued use of the Merrimack River as a source of water supply for the city of Lawrence. In the course of a few years after the filter had been constructed it became necessary for the Department in 1902 to urge the city to provide additional filtration facilities, but notwithstanding this advice the city neglected to enlarge the filter in season and only by the most extraordinary efforts was the necessity of introducing unfiltered river water into the mains avoided." Stopping there for a minute, would that illustration of municipal experience and dilatory action at all influence your judgment as between a source of supply which had to be pumped and stored and filtered and aerated and chlorinated, in contrast to a better original source of supply, and obtaining it by gravity? A. No, I don't think it would.

Q. You wouldn't take into consideration at all the human element as displayed in the conduct, in this country at any rate, of (1460) municipal affairs? A. I think the human element is, on the whole, more important in these stored supplies than it is in a treated supply, because in such storage supplies as now are used by Massachusetts the safety of the city depends on the efficacy of patrolmen and people who are watching the reservoirs, where there is a far greater element of danger than there would be in the operation of a modern mechanical treatment plant.

Q. What you say about stored waters of the Metropolitan District isn't borne out by any disease statistics that you have, is it? A. No.

Q. Boston's typhoid record is as good as any city, isn't it? A. Excellent, yes, and I think it would continue to be with a more scientific type of treatment.

Q. But the scientific type of treatment, for what it is worth, can be applied just as well to the stored waters of the Metropolitan District as to the polluted Merrimac water, can't it? A. That is what we are proposing to do, store the water of the Merrimac until it is about as pure as the present supplies, and then filter it and chlorinate it.

Q. So that the possible breakdown of the municipal government in this respect wouldn't affect your judgment at all as to where you went for the water? A. I can't conceive of a possibility of breakdown with a 60 or 90 days' storage and the treatment plan here provided.

Q. All right. Now, I will resume what I was reading: "This experience has been repeated time and again in the twenty years that have followed; and even at the present time the filter is inadequate for the purification of all of the water required for the city, and aid has been obtained from the neighboring town of North Andover, the inhabitants of which so reluctantly furnished water to the city on the ground that it would mean that they would constantly be called upon to provide for such emergencies. This fear has been realized and at the present time such assistance has come to be the regular course of procedure in providing the city of Lawrence with an adequate water supply. It thus appears that while the city has continued to use the polluted water of the Merrimac River its inhabitants have been menaced with the danger that unfiltered water would be introduced into the supply pipes, owing to the lack of adequate filtration facilities, not once but many times.

"Speaking scientifically, the question as to whether the city of Lawrence can continue to use the Merrimac River water for drinking must be answered in the affirmative. The river water can be purified so that it will be safe for drinking, so far as disease germs are concerned, even should its pollution become far greater than it now is. But even now the problem of

filtering the water of the Merrimac River is that of purifying one of the most polluted, if not the most seriously polluted, waters used by any city in the United States. *It can be done,* but sanitary science, prudence and economy agree that it *ought not to be done if another source of supply can possibly be obtained.* A water polluted by great quantities of sewage and by chemicals of various kinds discharged in the foul drainage of factories and mills, even though filtered and disinfected, cannot be regarded as a satisfactory source of public water supply. The question of the wisdom of the continued used of this river is one which, in view of the record of the past, admits of only one answer and that is, that under the circumstances the continued use of this water is a constant menace to the health of the people of the city."

(1463) MR. AVERILL. What are you reading from, Mr. Warren?

Q. Now, if such a response were made by the State Department of Health to the inquiry of the City Council of Providence, and that was signed by Eugene R. Kelley, Commissioner of Public Health—

MR. CALLAHAN. Lawrence, you mean.

MR. WARREN. Yes, what did I say?

MR. CALLAHAN. Providence.

MR. WARREN. Yes, Lawrence.

Q. You would think the Commissioner was wrong, if he made such a response, and that the people of Lawrence ought to continue to use that water? A. I think—the dangers are a little overdrawn, but it was essentially those considerations that he mentions that led us to insist on the storage reservoir, which completely alters that picture. It is exactly that fact that I tried to bring out in direct testimony, that while filtration and chlorination, as he says, could get by, could yield a safe water from the Merrimac River, we felt that it was a dangerous procedure and therefore the water should be stored and subjected to a 98 per cent purification before the filtration and chlorination.

(1459) that the illustration of municipal experience and dilatory action at Lawrence in the failure to construct additional filters as recommended by the Massachusetts Health Department in 1902 would not influence his judgment between a source of supply which had to be pumped, stored, filtered, aerated and chlorinated in contrast to a better original source of supply to be obtained by gravity; that 60 days' storage is a reasonable period and, if anything, a little longer than necessary; (1464) that using 60 days' storage for purification, an extra 30 can be used for drawing down; that the storage effects a removal of industrial wastes from gas houses including phenol wastes; (1465) that Lawrence has sometimes experienced odors, possibly due to such wastes in that part of their supply used without storage; (1466) that in his opinion, there are no cities and towns that would reasonably be expected to take water from the Merrimac below Lowell and Lawrence; (1466-1467) that he had not given consideration to what would be the effect of the diversion of 30 percent of the low flow of the Merrimac River upon the water supply of Lowell which gets its water from driven wells; that he hadn't supposed that these wells were located where they would be affected; (1469) that one reason the Metropolitan District should not go to the Ware and Swift Rivers is because, by doing so, they interfere with the requirements of other communities, more specifically those in Connecticut, for water for various purposes, of which water supply is one; that if an actual limitation of water is assumed, domestic use would have the prior claim to water over everything else; (1470) that he knows of no community in Connecticut that would be deprived of Connecticut River water for domestic supply purposes through the diversion of two per cent of the average flow of the Connecticut River by Massachusetts; that he doesn't think there are any such; that he doesn't think the recreational use of the Connecticut River would be interfered with by such diversion; (1471) that he sees no reason to anticipate algæ growth in the proposed Foster-Martin Reservoir; that the diversion of relatively pure

water from streams which will receive pollution below has an effect depending on the amount of diversion; that he would think that a diversion of 30 per cent of the dry season flow was pretty substantial; that he should think on the whole it would be worse for the communities below the point of diversion than the Ware-Swift situation, in which the War Department has required Massachusetts if it makes the diversion, to contribute something to the Connecticut River; (1475) that he had analytical results obtained on four samples from each of the nine Assabet supplies, from the Shawsheen supply, and from the Ipswich supply; (2256) that he did not consider possible future additional increases in population and sources of industrial pollution on the Assabet, Shawsheen and Sudbury Rivers as factors making the waters of the so-called Fifteen Watersheds unsuitable for treatment by filtration; that the fact that these supplies came from thickly populated areas was a real but minor element in judging suitability for treatment; that a large number of typhoid epidemics have occurred on almost uninhabited areas where the sewage from a single farm has got into a stream; (2257) that a limited population is no safeguard; that a considerable population on a watershed is not necessarily a menace; that Chestnut Hill distribution reservoir of Boston, surrounded by crowded apartment houses is much freer from danger of pollution than many remote lakes; that he thinks the only real test is the quality of the water finally delivered as indicated by the methods given by science; that analyses were made of the sources in the Fifteen Watershed plan and showed B. Coli content per 100 cubic centimeters varying from 25 on the Sudbury and 37 on Assabet G, up to 400 on Assabet D, and 412 on the Ipswich; that these can be compared with the standards set up by Mr. Streeter of the Public Health Service who says that for water suitable for treatment by filtration up to 5,000 are permissible; that all of these water supplies are of excellent quality for treatment by filtration and chlorination; (2258) that the probability of further increase of population has been greatly exaggerated; that declining birth rates, increasing death rates in later years of life and the great check in immigration have

led already to a marked slackening of the increase of population that has gone on in the last 50 years; that this country will rather shortly reach a period of stable population; (2259) that along with industrial developments in the future he looks for development of scientific methods of treating wastes, and scientific methods of improving water; that he agrees heartily with Mr. J. Waldo Smith that progress will be made in social comity and in coöperation between states, which is the real way to settle such problems as are involved in the Merrimac and the Connecticut; that he thinks the really sound lesson in regard to this question is to be drawn from the experience of Northwestern Europe where industrial development is on a colossal scale and where water supplies have been taken for 25 years from badly polluted streams running through industrial districts and treated with complete success; that the tendency of the future of this country is toward the more scientific, more intensive use of water resources, "rather than along the line of an attempt to discover the ever-receding gardens of Eden which require no repentance"; (2260) that short circuiting, such as occurred at Lake Owasco, could not occur in the proposed Foster-Martin reservoir; that the Lake Owasco case was a case in which raw sewage was discharged at the surface and being warm and containing fatty material, remained and was blown along as a pool in a single straight direction; that water is to be discharged into the Foster-Martin Reservoir at a depth of something like 20 to 40 feet and taken out at a similar depth; that a change of direction is involved; that any substantial amount of short circuiting is impossible; (2261) that breakdowns in water plants have been rare in relation to the number of plants operated; that they have been either due to flooding, or to break-down of smaller filter plants, or to instances where simple chlorination is used with no other precaution; (2262) that he knew of no instance in the history of public health of the failure of such a plan as is proposed for treatment of the Merrimac River; that the Merrimac River plan provides a triple safeguard; that one of the three elements of the protection might break down once in 10 years; that two of them might break down simultane-

ously once in 36,500 years; that three of them would fail to work on the same day once in 133,000,000 years; (2262) that every well regulated Health Department has its Division of Health Education and one of its chief duties is to produce modifications of public opinion in the line of scientific development, such as immunization against typhoid and diphtheria, control of tuberculosis, regulation of diet, and pasteurization of milk; (2264) that he believes it would be possible to convince the citizens of Massachusetts that the prejudice against the Merrimac supply was unreasonable; that he had examined Mr. Eddy's score of water supplies; (2265) that a water supply is supposed to be satisfactory if its total number of points equals 100; that a total of 91 can be obtained on raw water alone without reference to subsequent treatment used; that population per square mile is the governing factor in the score as any wide variation in that item cannot be overcome by other items; (2266) that water distilled from the Merrimac River or from the Lea River used by London would be penalized 40 to 60 points out of 100 because of the source from which it originally came; (2267) that the Eddy score is of no substantial significance with regard to the quality of a water; (2269) that the population of the United States in general is going to be stable very shortly and that his studies indicated that Massachusetts would not be exceptional in that regard; (2270) that if the ultimate quality of the water delivered were the same, the cost the same, and the relative effects upon other communities were the same, it would be a matter of indifference what the quality of the raw water was; (2271) that the Ware-Swift and the Wachusett supplies are a great deal better to start with than the Merrimac; and that he thinks that the public can be educated to accept water from a polluted source instead of from a pure source, if the polluted water were properly treated.

DR. FRANK E. WINSOR testified (1420) that the Merrimac River is being used and has been used for many years for commercial navigation as far as Haverhill, 20½ miles above the mouth of the river; (1421) that work on the Merrimac River in small portions has been done for many years by the United States Government; that he thinks that the Merrimac River has been considered since very early years as a navigable stream in Massachusetts and southern New Hampshire; that the Secretary of War in 1916 submitted a report to Congress and that this report covers a navigation project which was investigated concurrently by the Commonwealth of Massachusetts; (1422) that the United States Government in 1928 had spent about $905,000 on the Merrimac River for navigation by improving the entrance at the mouth of the river at Newburyport and by providing for a channel 7 feet deep and 150-feet wide up to Haverhill; (1424) that the report printed as House of Representatives Document No. 1813, Sixty-Fourth Congress, second session, and which was forwarded by the Secretary of War, printed January 2, 1917, covers a further investigation for extending the Merrimac River channel as far as Lowell, and in this report it is stated that there is no waterborne commerce on the section of the river between Lowell and Manchester, a distance of about 35 miles, and that the expense of improving this section of the river would not be justified under the conditions existing at the time of that report; that the Commonwealth of Massachusetts, in legislation enacted June 14th, 1914, appropriated $1,000,000 for the improvement of navigation on the Merrimac River from Hunt's Falls at Lowell, right (1425) below the Lowell Dam, by the construction of a channel 18 feet deep and 200 feet wide, provided that this sum should not be available or expended until Congress should approve a project and make an appropriation to improve that part of the river from the sea to a point opposite Ward Hill, Ward Hill being about one mile above the head of navigation at Haverhill; (1427) that the United States Government estimated that the work which would have to be done as its part by the Government would cost $6,-

000,000, exclusive of rights of way, terminals, bridges and some other expenses of that kind, in addition to the $1,000,000 suggested by Massachusetts; (1428) that in a report of the District Engineer of the War Department, it was stated that the interests to be affected were of sufficient magnitude to justify the United States in entering upon the project, providing that Massachusetts pay one-half of the costs and assume other responsibilities; that following the War other investigations have led the Board of Engineers for Rivers and Harbors to report to the Chief Engineer of the United States Army in July, 1923, that the improvement of the Merrimac River from Lowell to the sea was not considered advisable at that time; that the District Engineer made substantially this same statement some two years ago; (1429) that obviously the river comes under the Navigation Act of 1899; that it appears obvious that it is considered as navigable, not only in Massachusetts but also from the Massachusetts State line to Manchester in New Hampshire; that the Vesper Country Club bridge which connects Tyng's Island with the mainland and which was built about 1908, required a special act of Congress; (1430) that he has made no personal investigations or measurements as to the effect of possible diversions of the Merrimac River upon the navigable depth but that it is obvious that diversions will affect navigable depth; (1432) that the traffic in 1928 at Newburyport into Newburyport Harbor, which comes in through the mouth of the Merrimac River, was 59,203 tons with a value of $678,516.; that in that year the traffic on the river above Newburyport amounted to 58,933 tons with a value of $741,421.

(1435) Q. Now, assuming that the War Department applied the principle that it applied upon the Swift River application, during what period, on the average, would it be impossible to make a diversion of 200,000,000 gallons per day? A. If the War Department should make a ruling similar to that which has already been made relative to the diversion of the waters of the Swift River from the Connecticut River, namely, that diversion in the navigation period from June 1 to November

30, should not be permitted except when the flow exceeds 4,650 cubic feet per second at Sunderland, this corresponding to .58 of a cubic foot per second per square mile of drainage area, and that no water should be taken from the Merrimac River at Tyng's Island during 2.6 months in the average year, determined by records of 50 years from 1880 to 1929, there would be .4 of an additional month, on the average, in which only part of the 300 cubic feet per second supposed to be taken from the river would be permitted, thus making only nine months in the year during which the entire divergence proposed could be made, provided that the same rule applied proportionate to the drainage area.

Q. That 300 cubic feet per second that you just mentioned is equivalent to the 200,000,000 gallons per day? A. It is substantially.

Q. Which the Knowles' project contemplated? A. Yes.

(1436) that the proposed diversion of 200,000,000 gallons per day, as proposed, would be about 5% of the average flow of the Merrimac River and under the Knowles-Jacobs' project it is proposed to take 200,000,000 gallons per day—every day.

(1586) X. H. GOODNOUGH, Chief Engineer of the State Board of Health of Massachusetts, called by Massachusetts testified that there are a number of sources south and southeast of the Metropolitan District at Long, Assawompsett and others which are in Middleborough; that the Taunton River is in Bristol and Plymouth counties; that that part of Massachusetts south and southeast of the Metropolitan Water District is self-contained; that he doesn't think it has much of any surplus but that it has enough for present needs for a reasonable time in the future; that there is not any water to any substantial amount or quantity in that part of Massachusetts available for the Metropolitan District; (1587) that this district is south of the Old Colony line, which is the line between Massachusetts and Plymouth colonies; that it runs along down to Rhode Island (1588) to a point a little

south of the northeast corner of Rhode Island; that in 1895 an investigation and report was made by the Board of Health which is contained in House Document 500 of 1895; that he took part in that investigation and was assistant engineer; (1589) that the Merrimac River was investigated and considered; that the Merrimac River was rejected as a source of water supply; that as a result of that investigation the Wachusett Reservoir plan was adopted; (1590) that the Merrimac scheme was about 10% cheaper than the Wachusett plan and that they decided to recommend the Wachusett development to the Legislature; (1591) that the State Board of Health has jurisdiction of the sanitary condition of the rivers and waterways called inland waters in the statute; that the statutes apply to all waters with the exception of the Merrimac and Connecticut rivers and so much of the Concord river as lies within the city of Lowell, and the ponds and streams over which the Metropolitan Water Board has control; (1592) that the reason for the exception of the Connecticut and Merrimac rivers is that they were large rivers; that the Board cannot regulate the pollution on those two rivers except as the people along the rivers ask our advice as to what to do; that we can advise them but they are not obliged to follow it; (1593) that the City of Lynn has the right to take all of the flow of the Ipswich River in excess of 10,000,000 gallons a day just about a mile above the paper mill dam in Middletown; that Lynn is not allowed to take any water in the months of June to November, inclusive; that this is to maintain a proper flow in the Ipswich (1594) River and furnish waters to industries at Ipswich; that an investigation was made by the Legislature for water supply in Southern Essex County in 1911 to 1913; that there were several investigations and one or two by the State Board of Health and one by the Special Commission and that all of the cities and towns near the Ipswich River or its watershed were included in that investigation; (1598) that the next investigation was under the direction of the Legislature and is House Document 1550, Exhibit C-1; (1600) that that is the report in consequence of which the legislation was passed under which the present Metropolitan

Water Supply Commission is proceeding; that he is familiar with the Ware and Swift Rivers; that both rivers are entirely within Massachusetts; that he is familiar with the site of the proposed Swift reservoir and that that site is very advantageous for a reservoir; that it is large and would be (1601) deep; that the advantages of depth are the great improvement in quality of the water in storage and that in a season of shortage of water plenty of warning is given; that the site has almost no population or will have almost no population on the watershed; that the population today is very small and has been growing smaller for 70 years; (1602) that the site is the best site in Massachusetts for a reservoir; that the Ware and Swift supply as modified by the War Department will be sufficient to take care of the Metropolitan District until 1970; that at that time if the estimates of population are correct it will be necessary to obtain more water for the Metropolitan District; that by 1970 it is believed that a new water supply will be needed; that it is impossible to answer from where it will be gotten at that time; (1603) that there is more than a possibility that there may be some combination between cities and power companies for building great reservoirs, which will be used to their mutual advantage; that that is being done now; that there is such a plan being carried out now in Springfield; (1604) that it is impossible for him to say now where additional water is going to be sought; (1605) that if the additional water is going to be taken in western Massachusetts, he thinks that the Swift River is the best place in which to store it; that as far as present appearances go, it is possible to take the freshet flows of some of the other streams in the Connecticut Valley; that there are plenty of streams all through New England, especially in the Connecticut and Merrimac valleys, that would be used in connection with this reservoir; that he would not say that there is a probability that the streams in the Merrimac valley would be diverted into the Swift reservoir.

He further testified that he is somewhat familiar with the so-called Metropolitan Water Supply Investigating Commis-

sion, reported in House Document 900 of 1926, Exhibit C-2, that the engineers were Allen Hazen and Leonard Metcalf; (1606) that in this report Mr. Hazen recommended nine little reservoirs on the Assabet River watershed; that the Assabet River was considered in the 1895 report by Mr. Stearns, who said that it was possible to take certain small areas in the upper Assabet watershed and divert them into the Wachusett-Sudbury tunnel; that this is practically the same thing that Mr. Hazen suggested and that Mr. Jacobs has suggested; that the 1922 report mentioned the Assabet River and the possibility of taking certain watersheds there but did not recommend them; (1607) that in his report he said that they might get somewhere from 11,000,000 to 17,000,000 gallons a day out of it but that it was not advisable to take it; that it was a very small amount and that the diversions better be left for use as emergency supplies; that that is still his opinion except that diversions have to be made only at the times of very high flows, or else there will be trouble down below; (1608) that in order to make these diversions from those little watersheds, all of the works that Mr. Jacobs' plan shows, or some equivalent, would have to be put in if they were going to be used except the ones coming in by gravity; (1609) that if anything like 35,000,000 gallons per day were to be obtained all of the works that Mr. Jacobs recommended would have to be put in and that without using the pumps and the works, somewhere between 11,000,000 and 17,000,000 gallons per day could be obtained; that the Assabet is polluted; that it is one of the streams that the State Board of Health controls; that about thirty years ago one of the rivers of the state became very seriously polluted—the Neponset river; that the State Board of Health was asked to advise the legislature what to do; and they told the legislature that a more strenuous control, a stronger control, was necessary in the case of that river; and the legislature passed a law which enabled or directed the State Board of Health to prohibit the discharge of sewage into the river and to prevent the entrance of manufacturing waste unless it had been treated and purified, and directed the Board to advise the cities and

towns and persons as to how to purify; (1610) and very strenuous legislation was passed; next we had trouble with the Aberjona river in the north part of the district; and in 1914 the legislature passed an act directing the State Board of Health to prohibit the entrance of sewage or manufacturing waste unless treated, into the Assabet and to prevent the entrance of any other substance which might be injurious to public health or tend to create a nuisance, and specified how the report should be enforced; that he has a table showing the pollution in the Assabet and that he thinks none of it is above the proposed sources of withdrawal shown in Mr. Jacobs' plan; (1611) that if you remove the good water on the upper watershed, the tendency will be to increase the effect of pollution discharged into the river below, because of the lack of dilution; that Mr. Jacobs' plan providing for letting down 3,000,000 gallons a day would not be enough to take care of this pollution, because in all probability the flow of the river would be reduced still more materially and would have a tendency to increase the objectional conditions in the river; that they have done their very best to clean up the pollution but the reason that they cannot succeed is that they failed on the Neponset and Aberjona Rivers and have been obliged to have (1612) a sewer built up the whole length of the valley—in spite of all the treatment they could make; that this sewer is an intercepting sewer; that the purification plant broke down because it is very difficult to treat some of the wastes and that the best of treatment is not a purification in most all cases. There is always trouble in maintaining the works. Towns and factories neglect their work and it is very hard to keep them up; and our attorney general has told me that it is useless to go to court with some of these complaints because they are doing what he thinks is the best they can. Treated or purified sewage contains always a large amount of nitrates, which can create plant growths in the river; (1613) that they have many difficulties with filtration works; that sometimes the manufacturers put in wastes which puts the works out of business for a while; that doing their best, they are unable to secure satisfactory purification in the Neponset and Aberjona Valley and that he

fears they are going to have similar troubles in the Assabet and that he is sure that they would if any material quantity of water is diverted from it; that the proposition of diverting water from the Assabet was before the Legislature on the Hazen report; that he attended all or most of the hearings; that there was strong opposition before the Legislative Committee to taking any water from the Assabet River, the opposition being on the part of the inhabitants of the valley and of the Concord River valley and of the City of Lowell, through which the Concord River runs; that the Assabet runs into the Concord and the Concord runs into the Merrimac at Lowell; that the Assabet is highly developed industrially; that the Concord is in very flat condition to North Billerica and from there it is highly developed through to its mouth; that the industries in Lowell used to take a large amount of water in their processes but that he has not looked at them in very recent years; (1614) that some of the factories on the Assabet use great quantities of water in the manufacturing processes, the chief of which is the American Woolen Company's mill at Maynard, which apparently discharges in its waste, objectionable waste, 2,000,000 gallons a day, which is two-thirds of the amount of water which Mr. Jacobs was going to let down to dilute the river; that the State Board of Health requires 2,000,000 gallons a day to be treated by the American Woolen Company; that it is not pure after treatment; that it is his experience that whenever this effort is made to purify streams which are industrially developed (1615) somebody has to build an intercepting sewer; that in 1924 a plan was made to get rid of the sewage on the Merrimac river from Tyngsboro to the sea, and that they considered the alternative of putting in sewage disposal plants for each separate town, and for groups of cities and towns, sewage treatment works; that to build an intercepting sewer along the Merrimac river would cost about $20,000,000; that the project of building an intercepting sewer along the Merrimac river was considered because of the objectionable conditions complained of in that river below Lawrence and Haverhill down to the tidal portion

of the river several miles below Haverhill; that these objectionable conditions arise from (1616) the great pollution of the river by sewage and manufacturing wastes throughout its length; that if one-third of the low river flow above Lowell of the Merrimac river should be diverted by the Metropolitan District it would probably bring about the immediate construction of a sewage system or sewage disposal works, whichever they chose to build; that this would be an inevitable consequence of the diversion; (1619) that his opinion as to the desirability of the Assabet supply for the Metropolitan District, as outlined in Mr. Jacobs' project, or as outlined in Mr. Hazen's project, is the same as it was in his report in 1922; and that a little of it at the upper end that can be used by gravity is usable as a temporary supply in case of emergency; that in his opinion there is not a sufficient quantity of water to make it (1620) worthwhile unless it is confined strictly to the highest freshet flows; and it is of mighty little advantage except as an emergency supply; that the emergency supply would be eleven to seventeen million gallons per day at the outside; that the Merrimac river, as suggested by Mr. Jacobs, is in his opinion an objectionable supply for the Metropolitan District because it is beyond the police control of the state; that we know from experience that the state would have no chance to prevent pollution of any kind; (1621) that the Merrimac River comes into Massachusetts two or three miles above Tyng's Island; (1622) that from that point north is wholly within the state of New Hampshire; that he has navigated the Merrimac River from Haverhill to the sea; that it has been kept open for navigation at Lawrence; that there is a scheme lately for developing the Merrimac River as a waterway from Lowell to the sea; that the War Department has taken some part in it; (1623) that the question of navigation bears upon taking water from the Merrimac River because the river is very shallow below Lawrence and near Haverhill; and that he thinks lowering the water in the river would injure navigation; (1624) that the diversion of two hundred million gallons per day from the Merrimac River would reduce the

power in Lowell; that the reservoir of the Ipswich River proposed by Mr. Jacobs is substantially the same site proposed by Mr. Hazen, near the Salem turnpike; that he knows the site very well; (1625) that the reservoir proposed by Mr. Jacobs would be raised over what is known as the Wenham swamp; that he has examined that swamp in times past, and that it is a deep deposit of muck; that the greater portion of the reservoir would be a muck meadow; that from the standpoint of its availability as a reservoir the muck meadow would be likely to create a nuisance in two ways if used for a water supply: first, by the organic matter furnishing food for organic growths; and also by the presence of excessive organic growths; that he has known of organic growths in a reservoir in Massachusetts under similar conditions from which the odor was so intense that it could be smelled one-quarter to one-half a mile away; that when the reservoir is drained down very offensive odors will be given off from the exposed bottom; and that that is one of the chief causes of nuisance that is encountered in the summer and autumn seasons in this state; that the reservoir from which the offensive odors came, and which he mentioned above, is the Ludlow reservoir at Springfield; (1628) that the population in the Ipswich watershed is increasing very rapidly, as well as in the Shawsheen and Concord watersheds; (1629) that it is the policy of the Commonwealth to first provide that towns in another watershed shall first be provided for before water is taken for the Metropolitan District; that at Springfield, where Springfield took water from the southwest branch of the Westfield River, the law provided that if the flow of the river was not sufficient to dilute the sewage of Westfield that Springfield should build a new system of sewage disposal; (1630) that at Clinton the Water Board was required to construct a sewage disposal plant for the town of Clinton, and to maintain it until the town had grown to the point where the river would not care for its sewage; (1631) that there is a Massachusetts statute which requires the Metropolitan Board to build a larger sewer or to make other provisions for the disposal of the sewage of the city of Marlboro; that in the

Hazen-Assabet plan there was a compensating reservoir provided (1632) for the purpose of maintaining the flow of the river in dry weather, during the dryer six or eight months of the year, to a point which would be as high as it would have been if no water was taken; that the purpose of this compensating reservoir was to take care of the mills down the river; that in his opinion, if thirty-five million gallons were diverted from the upper Assabet and its tributaries, something of that sort would be essential; that he considers that the attitude of the public as regards the source from which their water supply is to be taken is a legitimate element for consideration in selecting a source; (1633) that that is a very strong element; that the people of Lawrence have objected most strenuously to the further use of the Merrimac River, to his knowledge, for twenty or twenty-five years; that there has not been any serious suggestion, before this one of Mr. Jacobs, that any city or town in Massachusetts in the Merrimac valley (1634) should take this water supply from that river; that it has never been thought they should go to the Merrimac River itself; that the Lawrence water is filtered; (1638) that the Metropolitan District has steadily had a tendency to go further west for its water supplies; that the reason for that is that they could get purer and better water in the higher regions and less inhabited regions in the central part of the state than in the immediate region east of the divide; that the fact that the Metropolitan District has been growing very rapidly and spread out so in later years, consequently overflowing into the adjacent watersheds, has accelerated and promoted the tendency to go to the west for water supplies; (1639) that in his opinion the public in the Metropolitan Water District would object very strenuously to the suggestion that the water for the District be taken from the Merrimac River; that the State Board of Health would consider it was a danger to the public health; that the legislature would consider it was a danger to the public; and that all the prominent citizens, in his opinion, would be against it; that this is a very important element for consideration in determining on a water supply

and is one which must always be considered most carefully; (1640) that it is his personal opinion that the Merrimac River is a very objectionable water supply for the Metropolitan District; that he thinks that if it was used that there are many people who would not drink the water; that he has heard the people of Lawrence beg the legislature year in and year out to find them some water supply so that they could get rid of using the Merrimac River; that he feels that they don't want it under any circumstances because of the sewage pollution above; that the sewage pollution is all through the river in New Hampshire and in Massachusetts; but that an enormous amount of it is in New Hampshire; that there were between four hundred thousand and five hundred thousand people in New Hampshire whose sewage drains into it; (1731) that there is one large industry on the Shawsheen River, the American Woolen Company; (1734) that in his opinion the Shawsheen is objectionable as a source of water supply for two reasons: one is, that there is a very large amount of swamp in the valleys and if reservoirs were built there they would be very expensive, or if the swamps were cleaned out they would be objectionable when the bottoms were exposed; and also the quality of the water would be objectionable; the chief objection, he thinks, is that the growth in the upper part of the watershed has been very rapid in the last few years; (1735) that Mr. Jacobs suggested in connection with the Fifteen Watershed Project, that a reservoir should be built on the Shawsheen, from which water should be pumped over the divide so that it might go into and increase the flow or supply in the Ipswich; that in his opinion this is objectionable on account of the pollution; the water is going to be very poor; and with a growing population trouble will result from reservoirs being drawn down; that that thing was fought out for years; that three or four times in the legislature years ago, the city of Boston tried to get the Shawsheen and was denied every time; that that was back between 1876 and 1886; that the Fifteen Watershed Project contemplated (1736) increasing the supply of water to the Metropolitan District by pumping water from the lower Sudbury to the Hobbs brook reservoir and thereby increasing the capacity of

the reservoir; that that was proposed by Mr. Hazen in House Document 900, but that he did not recommend it; that that is another region which is growing fast but that the difficulty with it is that the sewage disposals of Framingham, Natick and Marlboro were diverted out of the upper Sudbury watershed and is all disposed of inside that North Sudbury watershed; (1737) that there is also a considerable amount of manufacturing waste in the town of Framingham; that the river is very badly polluted for the six miles below Saxonville, which would be above the point of taking; that he thinks that the Shawsheen would be a decidedly objectionable source; that he does not believe that any of the departments would seriously consider the use of the lower Sudbury (1738) from the standpoint of public health, based on the pollution of the water and its general conditions; that even though the water were filtered and chlorinated, the probability is that the water would be objected to by the people who didn't want to drink polluted water; that they have tried that out many times and that the people are always of that opinion, as far as he could see; (1739) that he figures that the quantity required by the communities in or easily accessible from the Ipswich watershed in about 30 years will be about forty million gallons including what they take there now; that Essex County, which has an area of about 497 square miles and a population of about 500,000, together with the adjacent district in Middlesex County, is likely to want water there, and that the Ipswich is the only available source; (1740) that it is a very hard problem of water supply for the Ipswich communities because the amount is limited and the quality poor; (1741) if the cities of Salem and Beverly do not go into the Metropolitan District they will need the Ipswich water; that, from the standpoint of the present Metropolitan District, with such places as may be expected to come in, but excluding this Ipswich River group, there would be no real surplus of water for any great length of time for that district from the Ipswich River; (1742) that the towns along the north shore between Lynn and Gloucester are growing in population; that the towns are prosperous;

that that region is growing as a residential community; (1743) that there is a very large summer population along the coast and a tremendous summer population in Salisbury, the extreme northerly town against the sea; that there are excellent motor roads connecting that territory with the city of Boston, and that this has encouraged people to live there all the year round to get away from the city; that the town of Wilmington in the middle of the Ipswich watershed has increased 50% in population in the last five years; that this has a double effect on the water supply; it makes more people take the water and makes the water less desirable to take; that it makes a serious problem for the engineer of the State Board of Health to keep the (1744) river clean; (1744-A) that the following quotation at page 158 of House Document 1550 expresses his opinion today:

> "The Ipswich River and its tributaries are now used as a source of water supply by the cities of Lynn, Peabody, Salem and Beverly, and by the towns of Danvers, Saugus, Reading and Middleton. If used by the Metropolitan Water District, in addition to the municipalities which now take water from it or are likely to require water from this watershed in the future, there might be a small quantity of water remaining for the use of the Metropolitan Water District for a short time, but the large and rapidly growing municipalities in the part of the state in which it lies require that this watershed should be developed for their uses alone, and that this source should be kept for that purpose;"

(1745) that sometimes the state board of health recommends the use of filtered water, but that, if the people don't want it, the Department doesn't recommend it; that from his standpoint this water is not suitable for the Metropolitan District because the Metropolitan District doesn't want filtered water; (1746) that the trouble with filters is that, with these very soft waters, it is very difficult to filter the water and not make it corrosive; that it corrodes the pipes; that that is true even though there is storage first; in Cambridge the water is stored and filtered at present, and is very corrosive; and the

water, if it is corrosive, causes lead poisoning; that there was a very great epidemic of lead poisoning in Lowell some years ago; and that this was a lesson against taking corrosive waters; that by making the water harder this corrosiveness can be corrected (1747) but that it makes it very objectionable from a public health standpoint because people object to the hard water; boiler men object to it; (1749) that Lowell should be added as a possible addition to the Metropolitan District; that this will come, he believes, from a conduit from the Wachusett reservoir running right down there; that that has been planned and investigated; that a conduit from the Wachusett reservoir has been planned right down through to the Merrimac River watershed; that there is a stream called the Salmon brook which can be developed, and some of the upper waters of the Nashua River; (1750) that this is an interstate stream and flows from Massachusetts into New Hampshire; (1753) that in one case there is a mechanical filter in use where the hardness of the water was increased from two or three parts per million to ten parts per million; (1754) that the increase in hardness can be regulated scientifically by putting lime in; that the state board of health has recommended filtering time and time again where it is necessary; but the trouble is that the towns and the cities don't care (1755) to accept it; they say they want a water that is unfiltered; a great many of them say they don't want a water with "dope" in it; that is their expression; that they cried out very strenuously in 1926, when the matter came up in Mr. Hazen's plan for a water supply, where he proposed to filter the entire water supply of the Metropolitan District, and it was canvassed for three or four or five months in the legislature and absolutely rejected because they didn't want filtered water; that the policy is based on what the public demands,—and to get upland water which is relatively pure, rather than river water that requires considerable treatment; that the popular demand is always for clean water; that in his experience the legislature reflects and voices that very real public attitude regarding water supply in the Commonwealth;

that a water which had been stored for sixty days even, from the Merrimac, then filtered (1756) and chlorinated is always a menace; (1757) that after it has gone through that process he would not say that it is not fit for human consumption; that you can purify sewage so that it can be drunk; that, from the public health standpoint, water which went through that process would not be condemned as being unhealthy if it was properly done; that the water can be purified; that there is a danger of something breaking down in the purifying process; that there was an example of this in Lawrence some years after the filter was built when the filter broke down, causing polluted water in the city, resulting in quite a number of cases of typhoid fever; that, in the southern part of the state, a small filter was put in a village by an excellent engineer, but that it fell into hands that didn't understand it and the water ran though without any purification; (1758) that in Cambridge a filter broke down recently and was out of use for some four or five days, during which the people used raw water; that storage tends to purify water quite a bit; that it is possible to get a good deal of purification in a short time when the circumstances are right, but that it all depends on circumstances.

A. X. DOOLEY, a Witness from Massachusetts, testified (1659) that he had been a resident of Lawrence since October 1901, and all the rest of his life he had been a resident of Methuen, a suburb of Lawrence; that in 1915, he was made a member of a Water Supply Commission which was charged with finding a new source of Water Supply for the City of Lawrence; (1660) that at that time the Merrimac River was the source of a water supply for the city of Lawrence; that his commission employed Mr. Morris Knowles of Pittsburgh to make a study of the various proposed water supply projects; (1661) that this report recommended the taking of Bartlett Brook, a tributary of the Merrimac River; that this proposition was not approved by the State Board of Health

because the auxiliary supply of Bartlett Brook came from the waters of the state over New Hampshire line; that his commission was directed by the City Government to find a supply other than the Merrimac River because of the public feeling with reference to drinking Merrimac River water.

(1661) "Why were you so directed, do you know? A. Because of public feeling with reference to drinking Merrimac River water.

Q. What was that public feeling? A. Well, they knew the pollution of the water and they didn't like the smell and taste of it. They knew that almost all the towns on the Merrimac River above Lawrence dumped their raw sewage into that river. They knew that ten miles up the river from Lawrence the city of Lowell, a population of about one hundred thousand people, were pouring their raw sewage into the Merrimac River, and that was coming down to Lawrence in flood time in two hours.

Q. Now, Mr. Dooley, was there any aversion on the part of the public of Lawrence to drinking that water aside from the taste and smell of it? A. Well, yes, they had the aversion that they knew what the water was; they knew the Merrimac River was a public sewer and they objected to drinking sewage.

Q. And it was as a result of that public feeling that this Supply Commission of which you were a member was appointed, is that right? A. Yes.

Q. What about the sale of spring water in the city of Lawrence from the time you were made a member of this Commission up to the present time? Can you tell us anything about that? A. Well, in what way?

Q. Well, is there a large sale of it or a small sale or how does it compare with other cities? A. Just the same as it was for a number of years before this Commission was appointed. It is a very large sale, out of proportion with the sale of spring water in other places elsewhere that we had investigated.

(1663) Q. Do you know of your own knowledge whether or not spring water is used in any of the public buildings or domestic—or homes of the people of Lawrence? A. Yes, I do.

Q. To what extent is it so used, as far as you know?

A. Well, go into the courthouse up there, and you will find a bottle of spring water in every courtroom. You will find it in the Registry of Deeds, you will find it in some of the offices in the courthouse. If you go into the District Court you will also find spring water there.

MR. HOLDEN. You mean a bottle such as we have here in the courtroom, do you, Mr. Callahan?

THE WITNESS. Similar to that.

MR. CALLAHAN. I don't know. Is that what you mean, Mr. Dooley?

THE WITNESS. A tank similar to that, and it is spring water that it has in it; it is purchased from these water vendors.

Q. How about the schools? A. I haven't been in the schools myself. I haven't been in the schools to see them.

Q. So you don't know of your own knowledge as to that? A. Not of my own knowledge, no.

Q. Do you know anything about the proportions of spring water that are used in Lawrence in any year since you were on this Supply Commission? A. Yes.

Q. As compared with the total amount of water used? A. Yes.

Q. What can you tell us about that? A. In the year 1916, for instance, those statistics were gathered and it was then found that the amount of money paid for spring water by the (1664) people of Lawrence in that year was 55 per cent of the total amount of money paid to the city of Lawrence for public water for all purposes.

Q. That is, including bathing and washing purposes? A. And industrial pruposes.

Q. Have you any figures for any other year as to percentage? A. No, that was the year of Mr. Knowles' report, and it is the last year that we gathered them.

Q. How about the public feeling that you have described, Mr. Dooley, with reference to the aversion of the public to using that water? What is the present public feeling up there? A. Well, there is an index of

that apparent by the use of spring water right up to date. Water is delivered in almost every house in Lawrence for drinking purposes, much the same as milk is delivered there.

Q. Do you know what it costs? A. At the present time eight cents a gallon; that is, for anybody who buys one gallon. If an institution buys a larger amount, I think they get it at a lower rate.

(1665) Q. Do you think it is a fair statement to say that as far as the citizens of Lawrence are concerned their aversion to the use of that water is as great as it ever was? A. For drinking purposes, yes.

Q. (By Mr. Averill) However, you have not made any survey of the spring water since 1916? A. I have not.

Q. Does one company supply all the water? A. No; there were 15 different companies at that time, and I think there are about the same number today.

Q. Do they do any advertising? A. Yes.

Q. Have you seen any spring water used in Boston? A. I don't know whether it is spring water or not. I have had water in Boston.

Q. Do they have the same kind of bottles in the public buildings here? A. It is a glass bottle. I think as a general thing it is not the color of that glass (indicating bottle in the hearing room), and I think it is shaped a little different.

Q. You have not found this water supply yet? A. We have not found a water supply that would be adequate and the source of which would be in Massachusetts, and we could not get the approval of the State Board for taking water outside of Massachusetts. That was the unfortunate thing with Lawrence. There is an abundant supply north of Lawrence, but it is all in the state of New Hampshire. (1666) I might say further that there was a recommendation made to us to take the water from Salmon Brook, and our taking would have been in Dunstable, but Lowell made an objection to that. They said they were nearer to that resource than we were and, for that reason, they claimed they had a prior right to it. Besides, the State of New Hampshire was threatening to raise trouble because it would interfere with the water power of the Nashua.

MR. CHARLES D. HOWARD, an expert witness for Massachusetts testified (1645) that he is Chief of the Division of Chemistry and Sanitation of the Board of Health of New Hampshire; that incidental to his duties in connection with the control of water supplies in New Hampshire he has obtained considerable information with regard to stream pollution; (1647) that the unwritten or understood policy of the State of New Hampshire with regard to the treatment of waste has been to the effect that the communities shall not be burdened with the expense of sewage treatments so long as the sewage can be discharged without creating an offense; that there is no existing treatment of industrial wastes on the Merrimac River or any of its tributaries in New Hampshire; that there is no statute which requires such treatment; that the state of New Hampshire has not adopted any policy of requiring treatment or sewage works as far as streams are concerned; that in the case of lakes which are a potential source of water supply, there is control over them; that there is no treatment in any case of sewage which is discharged in New Hampshire into the Merrimac River; (1648) that the City of Franklin takes water and its water supply from a tributary of the Merrimac River; that the treatment given this supply is plain sedimentation but no coagulation, slow sand filtration and subsequent chlorination; (1649) that in a recent case where it was proposed to take water from a stream which had less pollution than the Merrimac, and with filtration, his board advised against this very strenuously, which (1650) amounted to the rejection of the proposition; (1651) that acting on the advice of the State Board of Health, bathing was prohibited in the Merrimac River just above the City of Concord; (1653) that so far as he knows, only one industry on the Merrimac River uses the water for manufacturing purposes and in that case, they do take water from the Merrimac, filter it and use it for boiler purposes, toilet flushing and, as was discovered, for use in their toilet rooms, for the use of their employees; that when that fact was learned, he required that in addition to filtration this water should be

chlorinated, which is now done; that his estimate is based on the experience gained in the course of his duties as Chief of the (1690) Division of Chemistry and Sanitation, New Hampshire Board of Health; that he has occupied the position of chemist of the Board of Health for the last 25 years; (1691) that his general knowledge is gained by investigations and observations that he had made in regard to the stream flow between these various points where sewage is deposited in the river; (1649) that to a greater or less extent he knows that all of the villages (1696) situated on the rivers, discharge their sewage into the river, and that he does not know of any better information regarding this matter than he has given today.

PERCY R. SANDERS, a witness offered by Massachusetts, testified (1697) that he had been Superintendent of the Concord (New Hampshire) Water Works since 1907; that he was familiar with the general sewage of water supply in and about Concord and in a general way throughout New Hampshire; (1698) that he regards the Merrimac River as the last place that the City of Concord would go to for its water; that this opinion is based on the population above Concord in the cities and towns, the sewage of which enters the river; that no person in Concord has any desire to drink water that is obtained from the Merrimac River; (1699) that an investigation of all possible sources of water supply of Concord was made by Metcalf and Eddy of Boston; that this report says: (1700) "Although the water of the Merrimac is abundant in quantity, it is polluted and would require treatment in a modern water filtration plant in order to use the supply for a municipal supply. The cost of the construction and operation of such a plant, together with the objection to the source, make this scheme undersirable;" that this report recommended the taking of water from an upland stream with a population of about 20 per square mile; (1702) that he finds storage to be very successful in removing bacteria; that storage and chlo-

rination are good things anyhow; that the water of the Merrimac could be filtered and used if you had to.

WILLIAM F. SULLIVAN, a witness for Massachusetts, testified (1703-1704) that he is mayor of the city of Nashua, New Hampshire, and president of the Pennichuck Water Works, a private company supplying the city of Nashua; that the present water supply of the City of Nashua (1704) is from ground water of flowing wells on the banks of Pennichuck Brook; (1705) that he does not believe the citizens of Nashua would desire or want the Merrimac River as (1706) a source of water supply, even though it were filtered and treated; that (1708) he does not know of any project to treat any of the sewage of the City of Nashua before going into the Merrimac River.

> (1709) "Q. Do you know what the public opinion is in Nashua, with reference to the general subject of treatment of sewerage or industrial wastes? A. They have no real atitude of mind towards it. We simply, like the rest of New Hampshire, I say, believe, are willing at this stage of industrial New England to favor industries as much as we can. We give them all the permissions and make it as light as possible for them to operate.
>
> Q. And that would mean that there would be no tendency to require them to treat industrial wastes or sewerage? A. Not at the present time."

MR. SAMUEL HOAR, a witness for Massachusetts, testified (1710) that in connection with the hearings in the Legislature on the so-called Gow report, House No. 900, Exhibit C-2, he represented the town of Concord and a woolen mill; (1712) that the town of Concord passed the following resolution:

> "Voted that the inhabitants of the town of Concord in town meeting assembled, hereby protest to the Massachusetts Legislature against the passage of that part

of House Bill No. 900, which in substance provides for Boston's future water supply: And further protests against the taking of all the water from the Sudbury reservoir in Framingham except one and one-half million gallons per day; because they believe that such taking on the Assabet and Sudbury watersheds will reduce the normal flow of these rivers to such an extent that serious damage to health and to property in Concord will result therefrom."

that this resolution was passed by a unanimous vote; (1713) that the people of Concord were concerned, because they felt that to interfere further with the flow of either one of these rivers would be a very serious detriment to the public health of Concord; that many of the people who had property on the river front felt this taking would be a serious damage to their real estate; (1714) that the compensating reservoir proposed was not acceptable to the people of Concord; that the Talbot Mills felt (1715) that the proposed taking would so reduce their water power that unless the mill went to steam power, it would have to go out of business; that the process water which the mill obtains at present is so dirty that any lessening of the flow would make it so much dirtier that it could not be used; (1716) that the sentiment of the Town of Concord would be the same today if a taking of water supply were proposed from the Assabet River for the Metropolitan District.

GEORGE A. BATES, a witness called for Massachusetts, testified (1761) that he is Mayor of Salem, that he is Chairman of the Ipswich River Protective Association, which was organized at the beginning of 1926 to protect the water supply needs and availability for the cities and towns of Essex County, to protect it against anyone who wanted to go in and take it away from them; that the water supply which the Association sought to protect was the whole watershed of the Ipswich River; (1762) that the cities of Salem, Beverly and Peabody and the town of Danvers, and many other towns in Essex County, are

today and have been for many years very badly in need of an additional source of supply; that if the source of supply that they had available by their natural rights and heritages was taken away from them, it would mean that they would have to go elsewhere for a water supply; that Wenham Lake is the only storage basin for the city of Salem, together with the Longham basin, which adds to it; that they are given the right under the statute to tap the Ipswich river during the course of the year for an additional supply and that they avail themselves of that right; that about a month and a half ago the lowest point in Wenham Lake since 1910 was reached, and that the situation there is really serious; that something definite must be done in order to bring about better water supply conditions for these cities; (1763) that the Hazen report contemplated going down into the Ipswich river valley and taking that source of supply for the Metropolitan District; that in Essex County the public was so aroused over the fact that the Metropolitan District contemplated taking their source of supply, that they immediately organized a fighting protective association, believing that the Ipswich river ought to be available for the cities and towns in Essex County, and because they were not altogether well informed by any study that had been made in the past that there was any available water for anybody outside; (1764) that as a result of that feeling a committee was organized of which he was elected Chairman, and that his recollection is that ninety to one hundred representatives of Essex County cities and towns went to the meeting; that they protested the passage of such legislation as was embodied in the Hazen report, and filed a resolve in the legislature asking for a further study of the situation; that the result of this was that they were excluded from the bill which eventually passed the legislature; that, as mayor of Salem, and as Chairman of the Protective Association, he was in a position to find out what the public's sentiment prevalent in Essex County was; that the public opinion in Essex was very strongly opposed to anyone else taking the water of the Ipswich river; that it was a very rational sentiment of men who were well

informed, and who believed that water which they needed for their own use was being taken away from them and they were being forced into something else that they didn't want to go into.

JOSEPH A. MC CARTHY, (1765) called by Massachusetts, testified that he was assistant at the Lawrence Experiment Station of the Massachusetts Department of Public Health and has been at Lawrence in that capacity since 1910 with the exception of the war years; that the purpose of that Station is to experiment on sewage purification in order to advise cities, towns and individuals; (1768) that about 1920 they put in operation there a modern mechanical filter which was a very complete modern plant with an area of .0001 of an acre for filtering Merrimac river water; that in 1922 and in 1924 they were unable to obtain satisfactory coagulation, and consequently to filter the water in the mechanical filter; that it is necessary in the use of a mechanical filter to coagulate the water; (1769) that coagulation collects inseparable particles of suspended matter, and to a certain degree, the bacteria, and clumps them into larger particles than their original condition; that it reduces the turbidity of the water and confines it to a small part of the influent water; that at the time when the satisfactory coagulation was not obtained, they tried to filter the water thereafter with unsatisfactory results; that the water which they tried to filter was not good; the color was high; there was turbidity and (1770) that, after a few hours, a precipitation would become evident; (1771) that these unsatisfactory conditions were found in the spring during the freshet conditions; that some of these unsatisfactory periods lasted, roughly, two weeks; that one lasted eighteen or nineteen days; that they had on a model scale every device that was known to be in public use at this time; that after the water went through the filter plants during these freshet conditions, it was not satisfactory for domestic purposes; (1772) that ordinary slow sand filtration could have been used on

such a water and that that would have taken care of it, but that forty or fifty or sixty times as much filtration area is required for slow sand filtration as for mechanical filtration; (1774) that outside of this experimental test his experience with rapid sand filters was during the war in France when he helped to construct and operate filters; that they were just about coming to a successful point when the war was over; that there was no reason why they couldn't have been a success if they had had a little more time; that during the tests the number of B. Coli per cubic centimeter of river water without the sewage (1775) ran between three thousand and ten thousand; that with the sewage added it ran as high as one hundred thousand; that he cannot tell what the average would be but that it would probably be around forty three thousand; that after going through this rapid sand filter the B. Coli per cubic centimeter of river water would be reduced from sixty six hundred down to about twenty or thirty; that these figures are average over the entire year of operation; (1776) that with forty three thousand B Coli content, with the sewage added the reduction after filtration would be down to ten to one thousand; that it would average thirty three B. Coli per cubic centimeter after filtration; that with enough chlorine this filtered water could be made safe bacterially.

Q. Have you conducted any experiments up at your station as to the quality of various waters from different water supplies? A. Not to any great extent, on account of the impossibility of getting sufficient supply of water to the station.

Q. Do you remember that some time in 1926 that you examined up at your station about eighty public supplies, including that of the Metropolitan District? A. Yes.

Q. Do you recall that from certain of these supplies, and I am reading now from the annual report of the Department of Public Health of the Commonwealth of Massachusetts for the year ending November 30, 1926:

"In certain of these supplies samples have been taken frequently during the year, but from others only oc-

casionally. Of the 207 samples of the Metropolitan water and impounded surface water, 90 per cent were of the required quality."

Is that correct? A. If it is there, it is undoubtedly so.

MR. WARREN. The question was whether you made experiments and whether that is the result?

THE WITNESS. Of course, I probably made the bacteriological examinations of those supplies.

Q. "Of the Lawrence supply, a polluted river water, filtered and then chlorinated, 702 examinations were made and 91 per cent passed the standard?" A. I should say that was it, yes.

Q. So that the Lawrence was one per cent higher than the Metropolitan District water. Can you tell me anything about the difference in cost below slow sand filters and rapid sand filters? A. I am not an engineer. I can't tell you anything of costs, except as we have them at Lawrence.

Q. All that you can practically say is as to what the tests showed you usually up there? A. What our small filter showed at Lawrence.

N. LEROY HAMMOND, a witness for Massachusetts (1821) employed by the Metropolitan District Water Supply Commission, as Division Engineer at Enfield, Massachusetts, testified that under the direction of Mr. Winsor, Chief Engineer of the Metropolitan District Water Supply Commission, he recently made certain soundings in Wenham Swamp, which underlies a large portion of the proposed Ipswich Reservoir, shown on Exhibit C-32; (1822) that the "dam site proposed by Jacobs 1930" at Willowdale is in the northeasterly corner of the Exhibit; (1823) that the soundings were made with one-half inch iron rods at various points shown by figures on the map, and that the figures represent the depth in feet of soft material and peat found by the witness; starting at the shore of the upland, as indicated, depths from two to four

feet were reached; thence going westerly to a short distance west of the brook shown on the map, a depth of 12 feet was reached; thence northerly in the vicinity of two brooks shown on the map, a depth of 22 feet was reached; thence extending northwesterly a depth of 28 feet was reached in soft material; thence northwesterly along the brook, a depth of 27½ feet was reached; that as they approached the river the water became deeper and the area became inaccessible; that the soundings were limited to those shown on the map; that from the progress of the soundings which he just described, and from experience in such matters, he judges that considerable of the area directly to the northwest of the point marked 27.5 would have peat or soft material extending at least 48 feet in depth and with the chance that somewhat greater depths might be reached; that in making these punchings or soundings the rods previously described were put down by one man simply by the strength of the hands placed on the top of the rod, and punched down; that hard bottom or so-called hard bottom was noted when considerable resistance to the end of the rod was felt, (1824-1825) in other words, when but very slight movement in advance was made by pressure on top of the rod; that as to the type of soil at the bottom of the soundings in this area, about 27.5, no samples were obtained of the material, but as the rod penetrated the lower limits of the soft material in his opinion there was either sand or gravel; that possibly clay may have been encountered; that there was no way of knowing what the material was except it was not bed rock, because it was somewhat resilient to the rods; that (1828) the soundings similiar to those made in Wenham Swamp were made in the low lands about 600 feet down stream from the southwesterly corner of Martin's Pond; (Exhibit C-33) that the depth of soft material varies from 4 feet near the shore of the upland of the swamp to a maximum of 28 feet in the vicinity of the brook; that (1829) in the particular sounding of 28 feet, the rod being open-ended, a very fine material which had the appearance of blue clay was brought up on the end of the rod; that however the material encountered as resistance was more or less resilient and was

not bedrock, nor apparently in the vicinity of bedrock; (1829) that the material in the hill directly northwest of the word "Salem" in the word "Salem and Lowell Railroad," was apparently a coarse gravel and sand—(1830) very porous, open material; that his personal opinion is that peat is objectionable because it contains a large quantity of organic material; that with a comparatively shallow storage of water on top of the peat, there must be more or less organic material mixed in with the water, which organic material would form food for microscopic organisms creating an objectionable water supply; that these growths would make the water more difficult to treat by filtration; (1831) that he would hardly know what growths might appear after the area was inundated, because of the change in character of the entire swamp; that there were no growths when he examined the swamp on March 15, 1930; that it is quite customary to treat reservoirs with copper sulphate to remove certain micro-organisms.

KARL R. KENNISON, witness for Massachusetts, (1834) designing engineer of the Metropolitan District Water Supply Commission since 1926, testified that he had read or heard, or both, Mr. Jacobs testimony about the Merrimac River plan; that (1835) he had made a study of different water supplies in eastern Massachusetts; that he believed that the diversion of 200 million gallons a day from the Merrimac River at or near Tyng's Island is impracticable if not impossible of operation because it takes such a large percentage of the low flow of the river, the entire low flow being (1836) needed for the industrial life of the Merrimac Valley and for navigation below Haverhill; that the cities of Lawrence and Lowell are two of the largest cities in the state and were built up around the water power of the Merrimac River; that their entire life depends upon the water; that to take away practically one-third of the low water flow would mean a practical confiscation of the pondage rights in Lowell and would surely bring about the intervention of the War Department as far

as navigation is concerned below Haverhill; that the modification of the plan as subsequently testified to by Mr. Jacobs would make the scheme physically possible of performance, but that the damage would be the same; that he understood the modifications as proposed by Mr. Jacobs in his subsequent testimony, proposed to count on all the storage in the Foster-Martin Reservoir to tide over a low water condition in the river; that (1838) it was not brought out in the record to what extent Mr. Jacobs planned to count on the storage; that Mr. Jacobs suggested that the 18 billion gallons storage might be drawn down to 10 billion; that that would mean 8 billion gallons drawn down, or 40 days supply at 200 million gallons a day; that the witness does not think that the modification makes any material difference in his conclusion that the Jacobs scheme is impracticable because it takes too much water out of the Merrimac River; that (1839) *the witness has made a study of what might be done with the Merrimac River provided that the Metropolitan District was forced to go to it for additional water;* that in his opinion a more practicable scheme would be what might be called flood water only from the Merrimac River; that there are several considerations entering into the determination of such a flood limit; first, that the War Department would undoubtedly require such a limit so far as navigation interests below Haverhill are concerned; that if a minimum flow below which no water could be diverted is taken in the vicinity of 0.6 cubic feet per second per square mile, it would correspond to a flow in the Merrimac River above Lowell of 2400 cubic feet per second; (1840) that if the action of the War Department on the Ware River is taken as a criterion, no diversion could be made whatever between June 15th and October 15th; that it is not known what the War Department might do on the Merrimac River but that it is clear that some limit would be set; that the sanitary conditions are more important; that the Merrimac River below Lowell, and as it passes thru Lawrence, is at times of low flow, a very highly polluted stream; that if any substantial quantity or even part of the low flow, were taken away, remedial

measures of a very drastic sort would be necessary; that therefore, again a flood flow proposition is indicated as the most feasible; that the principal criterion, though, that determined the amount which I have stated here, is specifically computed by taking the minimum requirements of the Proprietors of the Locks and Canals at Lowell, who are obligated to deliver to their various mills 3,600 cubic feet per second for 15 hours a day. That is the exact equivalent of 2,250 cubic feet per second for 24 hours a day. So that, just for the purpose of developing a diversion from the Merrimac to see what could be done, I have taken 2,250 cubic feet per second as a limit below which no flow could be taken from the Merrimac, and then have attempted to see what could be done in the way of getting a supply from the Metropolitan District that would be comparable in quantity with the Ware-Swift supply, although it seems to be impossible to make it comparable or anywhere near comparable in quality.

Q. You took that, as I understand, because that is the limit below which they could not go without interfering with the power requirements? A. Without interfering with the prime power requirements.

Q. That is what we call permanent power? A. Pardon me, it is not exactly the prime requirements. It is the contractual obligations of the Proprietors of the Locks and Canals.

Q. It is the permanent power that the power company is liable to supply its customer with? A. The permanent power is determined by the actual amount of water in the river, regardless of any legal documents bearing on the subject.

Q. It is the amount that is called for by the contracts? A. Yes.

Q. What did you say would be the limit if the War Department applied the Swift River diversion decision? A. Approximately 2400 cubic feet per second.

Q. On either basis you would arrive at pretty nearly the same figure? A. Yes, and I find when I compute the yields that I have to pull that limit down a little below 2400 in order to get this quantity out of it that is comparable with the Ware-Swift.

Q. You mean from the flood waters? A. It is necessary, I find, to set a limit as low as 2,250 in order to obtain a supply comparable in volume with the Ware and the Swift.

Q. By that you mean how much? A. 191,000,000 gallons per day in 1970.

Q. How much did you say? A. 191,000,000 gallons per day for the district.

Q. So that you had three reasons, practically, for taking that figure. A. Yes.

(1841) that he believes that this basis explained above would be as good a development, assuming that the district was obliged to go to the Merrimac River, whether it wanted to or not, neglecting that fact that it is really impossible to get as good a supply from the standpoint of quality; (1843) that he agrees with Mr. Jacobs that Merrimac River water ought to be treated by storing, filtering, aerating and chlorinating; that he was unable to find as much storage as he would like—not as much as Mr. Jacobs' scheme provided in proportion to the rate of flow through the filter plant; that the only place where this water that is to be pumped from the Merrimac River can be stored is in the Ipswich River Valley, combining the water of both streams, which necessitates taking the communities of Essex County into the District, and supplying their needs also, because they are already supplied from the Ipswich River sources; (1844) that the 191 million gallons per day is net increase in safe yield to the District supply; that the proposed system would have to be operated to a considerable extent in coordination with present sources by shutting off the flow from Wachusett Reservoir every wet period at the beginning of the spring and pumping that much more from the Ipswich and Merrimac Rivers; that the additional yield obtained from the Merrimac-Ipswich combination alone falls about 40 or 50 million gallons per day shy of the necessary quantity above this flood limit of 2250 cubic feet per second, but that if the two system (Wachusett and the Merrimac-Ipswich) are operated in coordination, more water can be obtained, as it obviates the possibility (1845) of water wasting from the

Ipswich storage reservoir because it is impossible to make that reservoir large enough; (1846) that to obtain 242 million gallons per day an available storage of 36 billion gallons is required, and allowing 10 billion gallons to remain in the reservoirs, a total capacity of 46 billion gallons is required; that this storage is required to obtain 191 million gallons per day net for the District—242 million gallons per day gross—the difference being made up of 42 million gallons per day to satisfy the Essex County communities' requirements in 1970, and 10 million gallons per day which must be let down the Ipswich River past the dam; that the only way to get 46 billion gallon storage is to raise the level of the upper basin by about 15 feet over that which Mr. Jacobs provided in his plan; that both Mr. Hazen and Mr. Jacobs planned an Ipswich Reservoir divided into two basins; (1847) that the *Jacobs' plan* of the Merrimac-Ipswich development as modified by witness Kennison, is shown on Exhibit D-25; that the storage in the Foster-Martin Reservoir is entirely inadequate to obtain the yield required to compare with the Ware-Swift supply; that he concluded that no enlargement of the Foster-Martin Reservoir is possible; (1848) that the 46 billion gallon reservoir is many times smaller than would be required for the economical development of the proposed supply, although this size will barely suffice; (1849) that the 46 billion gallon reservoir is formed by two basins; that it is impossible to get that storage in one basin because of the topography at the extreme right-hand corner of the watershed shown on Exhibit D-25, so that the limit in capacity is about 20 billion gallons, but that there is some physical possibility, however (however uneconomical) to obtain greater storage in the upper basin by raising the flow line from elevation 55 to 75; that Mr. Hazen used a flow line at elevation 55 and Mr. Jacobs one at 60; that this increase in flowage runs back into expensive real estate in the towns of Topsfield, North Reading and Middleton; (1852) that this so-called Kennison plan involves incorporating into the Merrimac River project the Ipswich River portion of what has been sometimes called the Fifteen-

Watershed Scheme; that when the Ipswich River is used as a storage basin in conjunction with the Merrimac River supply the possibility of getting 17 million gallons per day from the Ipswich River alone is sacrificed, and in the critically dry period all the water obtained is what the watershed itself will yield; (1855) that this scheme required works at the Merrimac River intakes having a capacity of 420 million gallons per day; that this is the rate at which the water would have to be pumped during those months of so-called flood flows (in excess of 2250 cubic feet per second); that the intake proposed by Mr. Kennison is at substantially the same point as that proposed by Mr. Jacobs; that instead of pumping through two pipe lines for the entire distance he has provided for pipe lines only about 2½ miles in length, to the head of a grade conduit, and taking advantage of the old Middlesex Canal to take the water by gravity into an open channel running into the upper end of the Ipswich Reservoir; that this channel would have to be prepared to take the water pumped for a distance of about three miles; that his scheme provides for filter beds located at the south end of the reservoir instead of at the north end as proposed by Mr. Jacobs, in order to save money; (1857) that his scheme is one which would yield a supply of 191 million gallons per day in 1970; that he believes that the depreciation, as a whole, of this proposed supply would be high, as compared to the Ware-Swift; that in discussing depreciation as a whole he has in mind that different supplies of the Metropolitan District have had to be abandoned because they were close to the Metropolitan center; that in his opinion this plan will ultimately have to be abandoned because it is putting the water supply into an area in which the population is rapidly increasing instead of one in which the population is decreasing, as in the case of the Swift; (1859) that while the major jart of this supply comes from the Merrimac River, the reservoir is in the rapidly growing suburban district in Essex County; that this fact would indicate that the supply would have high depreciation value; that when he said population as an index, he had in mind population as a cri-

terion of industrial development also; that what might happen to the Merrimac River in New Hampshire has been omitted entirely in consideration of quality, except that he has allowed 10 billion gallons to be left in the reservoir as a minimum; that this is the only consideration of quality which he has allowed to enter into this comparison; that the Foster-Martin Reservoir has been discarded because if 10 billion gallons is left in the reservoir, it would net only eight billion gallons; that the cost of this is so much that the storage can be obtained more economically (1860) in the Ipswich basin itself; that the Foster-Martin Reservoir storage could be added by providing additional pipe lines to it from the pumps; that in discussing leaving 22% of the capacity of the Ipswich Reservoir as a minimum, it would be necessary to leave a much smaller proportion of that in the upper basin, and a larger proportion in the lower, because the lower basin is the one from which the filter plant directly takes its water, so that this plan necessitates (1861) drawing almost to the very dregs, regardless of the fact that that is not desirable from the standpoint of quality; that Wachusett Reservoir, with a total capacity of 65 billion gallons, has never been drawn lower than 30 billion gallons; that this is a larger percent of minimum water kept in the reservoir than he has been discussing for the Ipswich River Reservoir; that the filter plant must have a total capacity of 342 million gallons per day made up of 191 million gallons per day for the District, 41 million gallons per day for the communities in Essex County, an additional 100 million gallons per day to take care of the necessary coordinate operation with the present sources and approximately 10 million gallons per day extra of wash water and aeration losses in the process of filtration, but that in the estimates of cost he has included only about 320 million gallons per day because (1862) the excess filter capacity to provide for Essex County Community would not be chargeable to the District; (1863) that the filters would have had to have an overload capacity to take care of such conditions as occurred in the District's demand in 1918; that this excess demand is

sometimes caused by a cold winter when people leave their faucets running to keep from freezing, other times by dry periods when an excessive amount of water is used for watering lawns and gardens; that, as a matter of fact, the maximum week in 1918 of consumption was 40% more than the ordinary expected capacity during those years; that he has allowed only 25% excess capacity in the pipe lines; (1865) that the Ware-Swift supply has that same sort of excess capacity in the aqueducts; that in 1918 the excess capacity (1866) was taken care of by the aqueducts without even approaching their capacity; that he has chosen as the dam site for the lower reservoir the site used by Mr. Hazen, who made a very exhaustive study of that lower basin for the water supply of the cities of Salem and Beverly, rather than the site a little farther down the stream which Mr. Jacobs used, the principal reason being that it is very difficult to take care of diverting the sewage and drainage of Topsfield if the lower site is chosen; that his plan, with the shorter pipe line and grade conduit involves pumping against a lower head than Mr. Jacob's plan; (1874) that from his experience in water supply engineering he would say that a source of supply, polluted, was entirely unacceptable to the people who elect representatives to the Massachusetts Legislature; that from listening to hearings before various legislative committees in which the views are expressed, he would judge that public opinion was very much against polluted sources of water supply; that from those hearings he learned that the communities and industries on the Assabet River considered that any such development as Mr. Hazen proposed, and such as Mr. Jacobs now proposes, to cut off the entire upper flowage of the Assabet, would be regarded (1874) by them as entirely unwarranted, and such a project would be fought by them in the legislature; that the most outstanding fact about those legislative hearings on the Gow plan, so-called (Ex. C-2) was the fact that the Essex County communities, as a whole, considered that the Ipswich River belonged to them for their water supply, and that they would fight any such project in the legislature to the best of their ability; that any such project as the Metropolitan

District going up to Essex County and taking that supply (which, it was even admitted by Mr. Hazen and Mr. Gow, and others, would ultimately be used entirely for the Essex County communities) would simply be a makeshift for the District; that he thinks the principal reason why they were opposed to it was not necessarily the actual taking of the water, but the development in their growing community of a large reservoir that would prohibit their natural growth, and also that by necessity, its operation, an account of its being such a shallow reservoir, it would make an unsightly and probably a foul smeelling mess in that general locality of high real estate values; (1876) that he does not consider that this would be at all an ideal reservoir site, and in order to make it acceptable at all considerable treatment of the bottom would have to be made; that he has included in his estimate figures similar to what Mr. Hazen included for putting in a dredge and working continuously to improve the shallow flowage areas; that, even so, he is not sure from any personal knowledge that it could be made acceptable, because he knows that the basin is filled with a deep amount of peat deposits; that by spending an excessive amount of money the peat deposits can be covered up with clean gravel; that a peat bottom is objectionable because it tends to create an excessively high color, and would also create growths of weeds when the water is shallow; (1877) that the communities in the Ipswich valley appear to be growing at a more rapid rate than any other suburban area and that it is a fairly well settled section anyway; (1941) that the nine little watersheds on the Assabet River suggested by Mr. Jacobs in what is called the Fifteen-Watershed Plan, constitute the only drainage to the north of this entire section 20 miles west of Boston; that, in his opinion, as a practical matter, the water of a number of small systems with one main system of better quality is bound to result in a loss of capacity in those smaller systems, because it is contrary to human nature to start to use those smaller scattered, more expensive and inferior sources as soon as they ought to be used in the spring in order to obtain the safe yield, which is theoretically computed as available from such sources;

that he does not consider that the Shawsheen and Lower Sudbury should be considered in any sort of comparison; that it is possible to take some of the head waters of the Assabet and obtain, simply as an emergency source for the Metropolitan District, somewhere between 11 and 15 million gallons per day, as has been suggested in (Exhibit C-1); that in an emergency developed by some earthquake, for instance, the District might be forced to develop an emergency supply there, but that it would not be looked to for a regular supply certainly (1943) not in 1970; that the population of the entire Assabet watershed is approximately 172 persons per sq. mile, and that there are approximately 50,000 people already taking their water supply from that area outside of the District.

Q. (Mr. Averill) Mr. Kennison, if by any chance you couldn't get the Ware and Swift Rivers, couldn't you develop the water supply which you have testified today? By seriously impairing the industrial and other growths of this eastern part of Massachusetts, it is physically possible to obtain the water.

Q. It can be developed? A. It certainly can be dammed. It is physically possible.

Q. How long have you been working on this plan, this combination Merrimac-Ipswich plan? A. Since the testimony in this case has led our attorney to suggest that we see if we cannot make the best possible scheme out of the Merrimac and see really what could be done.

Q. (By Mr. Warren) Just one moment. You spoke about the impairment of the industrial prosperity of the eastern Massachusetts District. What do you mean by that? A. I believe there is an exhibit showing the relative growth of the (1945) eastern part of Massachusetts compared with the western part, which indicated that this is a rapidly growing section of the State, and we cannot devote large areas such as a big storage basin in the Ipswich Valley for water supply purposes without retarding the growth.

Q. And do you think it is a legitimate consideration to which hydraulic or water supply engineers should give attention, the industrial need of water for process and other purposes in industry? A. I think it is very important, yes.

MR. WARREN. That is all.

MR. AVERILL. You don't believe that water supply for domestic purposes comes first, before everything?

THE WITNESS. Yes.

MR. AVERILL. All right, that is all.

Q. But you believe with this fine supply from the Ware and Swift Rivers, with only 30 or 40 people per square mile, that that ought to be available water, don't you? A. Yes.

Q. And by using that you haven't got to ruin the industries in the eastern part of the State and leave that water going to waste up there? A. No.

(2116) that Exhibit D-29 is a tabulation of expenditures for the Ware-Swift project to March, 1930; (2117) that Exhibit D-30 is a table showing the comparison of the Connecticut and the Merrimac rivers with respect to navigation and diversion; that Exhibit D-31 is a tabulation consisting of comparisons of growth of population on the Ware, Swift and Merrimac watersheds; that an estimate of water supply requirements in Northeastern Massachusetts, including Worcester and other westerly communities depending on the Metropolitan District is Exhibit D-32.

Q. (By MR. AVERILL) If by any chance you cannot get the Ware and Swift, it is going to be necessary for you to go to the Merrimac, isn't it? A. It appears it would be necessary to gradually curtail the growth of the district to that extent.

Q. Do you mean to say as an engineer that if you had to you could not furnish a water supply sufficient for Boston by 1970, from the Merrimac and other sources in eastern Massachusetts? A. I think it is entirely probable that industries contemplating establishment in Boston might move somewhere else if they could not get a proper water supply.

Q. As an engineer, you do not want to go on record as saying that you could not furnish Boston with a supply for 1970, if you had to, from the Merrimac and other eastern supplies? A. It is physically possible to do so.

Q. (By Mr. Warren) But, taking into consideration all the elements that govern the selection of a source of water supply, (2130) you think, as an engineer, that it is necessary to go to the Ware and Swift Rivers? A. I do.

WILLIAM F. UHL, consulting engineer, called by Massachusetts, testified (1781) that he has been consulting engineer for some of the lessees of the water power companies on the Merrimac river; (1782) that he is familiar with the water power of the Proprietors of the Locks and Canals, which is the power company at Lowell, as well as with the Essex Company at Lawrence; that these companies are water companies and sell mill power under perpetual leases; that the Essex company was organized about 1845 and the company at Lowell about 1830; (1784) that the water power development at Lowell consists of a dam constructed across the river, which diverts water into two principal canals, which in turn conduct the water to where the water power wheels are situated; (1785) that the total horsepower developed at Lowell is thirty thousand horsepower; of which eleven thousand is permanent power and the balance surplus power; that the eleven thousand horsepower is available at least fifty-four hours a week, the rest being available at times more or less depending upon the flow of the stream; that the balance of nineteen thousand horsepower is more or less uncertain depending upon the flow; (1787) that he is familiar with Mr. Jacobs' project to the extent of having studied Mr. Jacobs testimony for taking water from the Merrimac river only to the extent that it involves the taking of two hundred million gallons per day out of the Lowell pond, which is the pond extending about nineteen miles upstream above the dam; that he figured on Mr. Jacobs' project taking two hundred million gallons per day; (1789) that the Lawrence layout consists of a dam and two canals, one on each side of the river, each running practically parallel with the river; that the mills are between the canals and the river and draw their water from the canal and

spill it into the river without any intervening pond; that the dam at Lawrence backs water up practically a distance of nine miles; (1790) that assuming that the diversion is simply a diversion out of this pond without any interference in the pondage control, it is purely a power loss represented by the quantity of water; that two hundred million gallons a day is the equivalent of three hundred and ten cubic feet per second which would come directly out of the permanent mill powers, permanent leases; that the low flow of the Merrimac river is just about sufficient to produce the water for the permanent mill powers; so that, if the three hundred ten cubic feet per second is diverted, about twenty-five per cent of the permanent mill power will be destroyed; that, in addition to that a loss of power, from thirty to forty per cent of the time during the low flow periods in permanent and surplus horsepower hours, as well as the capacity loss, would result; that, if the diversion is made, the mills will have to provide for approximately 2130 kilowatts more standby power, either in the way of steam capacity or purchased electric current, and will in addition have to supply something over six million kilowatt hours of power; that, if the diversion interferes with the pondage control by the Proprietors of the Locks and Canals, they will, in addition to this twenty-one hundred and thirty kilowatts of capacity which will be lost, have an additional loss of capacity depending upon the interference with pondage control; and insofar as the pondage of water over week ends and overnight is concerned, (the mills operate only about fifty-four hours a week out of a total of (1791) 168 hours in a week), water will have to be stored and it will be necessary to draw from or pull this pond as much as six to seven feet by Saturday noon in order to be able to pond the week end flows, and smaller amounts overnight; that, since this pond is only about fifteen feet deep, it is probable that the Water Supply Commission will have to make an agreement with this power company to maintain its pond at an elevation perhaps not more and not less than two or three feet below this dam or it would be necessary to build an additional dam some place in the Lowell ponds in order to assure themselves of always

having sufficient depth of water at their intake; that, therefore, if this interference with the mill pond should be brought about by taking the water from the mill pond continuously, all or practically all of the permanent power would be destroyed at those places; that the reason why the interference with the control of the pond makes so much difference is because it would make it impossible to pond the water over the week ends and overnight at will as is now being done, and the assurance of always having 1200 cubic feet per second for short periods would be destroyed; (1792) that, if the two hundred million gallons of water were taken out during the ten per cent of the time when the flow is the greatest, it would probably have no effect whatever; (1793) that where there is surplus water in the river, that water is used to increase the water power in the mills; and when the surplus water is not there the mills have to get that power either by steam or by electric current; (1794) that there is a possibility of redevelopment at Lowell and Lawrence, and tentative plans to that extent have been made as far as ten years ago; that this, if carried out, would mean a much more complete utilization of this power; that, in his opinion, both of these power companies may abandon their present use of the property and develop instead single hydro-electric plants; that in his opinion that will be done within a very short period of time and (1795) will very largely increase the utilization of these water powers; (1795) that the estimate of damages, assuming no interference with pondage control, for both Lowell and Lawrence, under this plan would be $2,851,000, which would not take into consideration any community damage due to the reduction of this important local natural resource; (1796) that by this he means that every home owner and every merchant would be affected by a reduction of this water power in Lowell and Lawrence; that he would not attempt to compute this damage, which is an indirect damage; that it would be a very real damage to both Lowell and Lawrence; that if the pondage control was interfered with the damage for both Lowell and Lawrence would be about $5,410,000, without including anything for the community

damage; (1798) assuming that the redevelopment of which he spoke was engaged in, and that there was interference with the pondage control, the damage might run at least as high as eleven million dollars, and if assuming no interference with pondage control, the damage would be about $5,466,000.

JAMES F. SANBORN, of New York City, testified (1878) that he is a consulting engineer; (1879) that he was employed by the Metropolitan Water and Sewerage Board on the development at the Wachusett reservoir; that he has heard Mr. Kennison testify as to the plan which he described; that he has heard the plan outlined by Mr. Jacobs and confirmed by Mr. Gregory; that the plan outlined by Mr. Jacobs would interfere with the water in the Merrimac river; that there would not be sufficient water to permit a daily draft of the amount required by Mr. Jacobs' plan; (1880) that he does not believe that the amount of storage in the Foster-Martin reservoir, proposed by other witnesses, could be maintained; (1882) that he believes that the water from the Merrimac river would be difficult to treat, but that he is not an expert on water treatment; that the water of the Merrimac river (1883) would not start with as good quality as if it came from the Ware and the Swift; (1884) that the plan would not work out well; that you would have to contend with bad water at times of low flow in the river and when you had to stop pumping for several days at a time due to interference with the flow, you would have bad operating conditions in the reservoir due to drawing it down; that even if you could buy the right to draw at any time, there would still be poor water at times of low flow; that there would be perhaps also difficulty with the War Department requirements, which would limit the opportunity for draft there at periods of low flow; that they have discussed the probable demand of the War Department, based on the demands in the Ware and Swift case; (1886) that he is familiar with the plan which Mr. Kennison

outlined; (1888) that, considering the limitations assumed by him, the plan outlined by Mr. Kennison is better than Mr. Jacobs' plan, either with or without the modifications which he later suggested to it; that it is the best plan that can be devised for this project of taking water from the Merrimac river for use of the Metropolitan Water District; that the limitations which he assumed are those stated by Mr. Kennison; (1889) that the reservoir provided in the Kennison plan is not big enough for the best results in taking water from the Merrimac river; (1890) that Mr. Kennison's plan is the best plan that has occurred to him or to his associates; that it is a very poor plan and not to be considered if you could go to the Ware-Swift; that if you could go to the Ware-Swift, they would not think of adopting it; (1891) that, if the Kennison plan were put up to him as a plan for supplying the Metropolitan District with water, he would want to examine the situation very thoroughly to see if any other supplies were available; that the raw water from the Merrimac river is very inferior water compared with the Ware-Swift supply; (1892) that the quality of the water is affected very much by the depth of the reservoir; that with a full reservoir you get a fairly good water, but if you draw the reservoir down so that you expose the shallow areas you would get a very poor water; that if the reservoir at the Foster-Martin pond were drawn down (1893) to ten billion gallons, or ten feet instead of eighteen feet deep, and no pumping was done from the river during the lower stages, you are liable to get some very bad water; that an 18 billion gallon reservoir would not be sufficient to take care of the flood river flows of the Merrimac river, and would not take care of whatever larger amounts it would be necessary to divert in order to make up for the days when no diversion could take place; that the reservoir would be large enough if you could count on diverting two hundred million gallons every day in the year; (1894) that this assumes that there is perfect storage in the reservoir and that there was not rapid travel of the water through the reservoir; (1895) that if no water could be diverted from the river for a period of thirty

days, and water was drawn from this reservoir during this period, that would take six billion gallons out of storage in the reservoir and a condition would result when they feel very strongly that it would be a serious operating condition; (1896) that at the end of sixty days, if no water could be diverted, there would be about six billion gallons left in the reservoir, and that situation would be still worse; that the scheme would not be a good scheme, and would break down somewhere in between the thirty day and the sixty day period; (1897) that storage alone in the Foster-Martin reservoir would not bring the water up to the standard of the Ware-Swift water; that, if the Merrimac river water was treated as Mr. Jacobs planned to have it treated, stored in the Foster-Martin reservoir for ninety days, filtered, chlorinated, aerated and coagulated, it is (1898) his opinion that the water would not be as good as from the stored Wachusett reservoir; that his judgment is based partly on the difficulty of conducting a perfect process; that, if the Ware-Swift water which was brought into the Wachusett reservoir is chlorinated, he feels pretty sure that that water would be better than Merrimac river water treated as proposed by Mr. Jacobs; that if the Ware-Swift water were filtered as well as chlorinated, the Ware-Swift water would be better than the Merrimac river water; (1899) that referring to the future of the supply from the Merrimac river, studies have been made of the population increase in the area of the Merrimac river and in New Hampshire, and the indication is strongly that in forty or fifty years there will be a strong inclination to abandon such a supply; that the growth of the population from the Boston district is going up into that watershed on account of the rapid increase and use of automobiles; that those studies indicate that in about forty or fifty years there will be a density of population there such as to warrant the assertion that the reservoir would be (1900) badly polluted; that if that happens it would be necessary to look elsewhere for a supply; (1901) that the Ware-Swift watershed is an area of decreasing population and of decreasing industry; that a great many small industries are being abandoned in

the upper part of the watershed; that it is an elevated area of hard rock and sandy soil, admirably adapted to an upland supply; that pure soft water can be obtained from such an area and that it is a more desirable watershed from which to draw; that, eliminating the question of cost, the Ware-Swift scheme is better than the Jacobs scheme, either in its original form or as modified, or in the form as dressed up by Mr. Kennison; that the quality of the water is better in the Ware-Swift watershed; (1902) that for a big water supply it is considered better to go to the pure source and that that is done very generally in the eastern country; that that is done wherever there is a pure source available; that public opinion with respect to a source for a water supply is always considered; that he agrees with Mr. Jacobs that public opinion is sometimes the controlling consideration; that he has studied the suggestion of Mr. Jacobs which was Mr. Hazen's suggestion with some alterations and which has frequently been referred to as the Fifteen Watershed project; (1903) that it is open to the general objection made to the Merrimac supply, that those areas are already well polluted and have an increasing population, so that there would be a constant tendency to increase pollution and be faced with the expectation of abandoning some of the area after a few years; that it is too near the center of population and industry; that as to that portion of this plan which would obtain seventy millions gallons per day from the Ipswich river it is his opinion that there would be a tendency to curtail it as time went on and ultimately to abandon it; that the Assabet portion of this plan provided for about twenty-seven million gallons a day from nine different watersheds, with pumping in some instances, and filtration of the whole supply; that the lower Sudbury portion of this plan involved pumping and furnishing filters to supply seventeen more million gallons; (1904) that the Shawsheen portion of the Fifteen Watershed plan involved pumping also; that he does not like the Fifteen Watershed plan at all; that there is the objection of providing four filter plans and that there is objection of the difficulty in controlling the pollution; that in

his opinion it would not be a permanent source for additional water supply for the Metropolitan District; that it is his opinion that popular opinion would force the abandonment of the Merrimac river supply if it should be adopted at the present time; (1909) that he is not an expert in water treatment; (1910) that his opinions previously given are his opinions as a water supply man and not as a result of study of any analyses and that he has had no details; (1911) that he understands that the plan developed by Mr. Kennison was developed since the Jacobs' plan, so-called, was submitted to the court in this case; that the Kennison plan is a combined plan for the utilization of the waters in the Ipswich valley (1912) and that when necessary that supply is augmented by a draft from the Merrimac river; that the first stage in the Kennison plan is to take fifty million gallons a day from the Ipswich river for the Metropolitan District; that this allows thirty million gallons net for the population now getting water from that source; (1913) that these communities are using at the present time about eight million gallons a day; that he means the people in Essex County are drawing that amount from the Ipswich river, supplementing their other supply, and this thereby avoids adding any considerable body of consumers to be supplied from the Metropolitan District; (1914) that he estimates the available water in the Ipswich river at eighty million gallons a day as developed by this storage; (1915) that if six billion gallons are drawn out of the Foster-Martin reservoir it would lower the reservoir about five feet; (1916) that when the Foster-Martin reservoir was drawn down from eighteen billion gallons to twelve billion gallons, the area that would be exposed would be all sand, rock, pavement and loam; that the witnesses's objection is not so much to the part of the reservoir that is above water but rather to the decrease which would result over the remainder, and the probability of algæ hatching, and also the fact that you have only sixty days of storage, and the further difficulty of the entering water forming a continuous flow and getting to the outlet in less than sixty days; that the smaller the reservoir the greater the liability of that

happening is; (1926) that the treatment of water by filtration and other devices for the removal of bacteria and organisms is a specialty; that bacteriologists and filter plant operators are particularly experienced in that line and he is not that kind of an expert.

MR. FRANK A. BARBOUR, an expert witness for Massachusetts, testified (1945) that he is a consulting engineer specializing in water supply and sewage disposal; (1951) that he is familiar with the water supplies and water consumption in Eastern Massachusetts; that during the hearings on the relative merits of the Ware-Swift and the so-called Hazen project, he represented the town of Peabody and attended the majority of the hearings before the legislature; that he has studied the Merrimac project as submitted by Connecticut; that with reference to the Merrimac as a water supply, as suggested by Mr. Jacobs in his testimony, (1952) he thinks the first thing to be considered is the necessity of taking the water immediately below the New Hampshire line, which at once emphasizes the fact that it is taken at a point where Massachusetts has no control over the amount of sewage or industrial waste which may be admitted to the stream; that in 1920 there were three hundred and fifty thousand people in the Merrimac valley watershed above the proposed intake at Tyngs Island, one hundred and thirty thousand of which were in the three cities of Nashua, Manchester and Concord, located on the main stream at distances respectively of twenty, twenty-five and forty-five miles above the proposed intake; that the discharge of these cities enters the Merrimac River without treatment; that he thinks a half a million people would probably be the population within a period which might be well taken into account in the present case; that he knows of some seventy-five plants on the river, including twenty-five paper mills, three tanneries, one rendering works, two cellulose product works, eleven cotton mills, twenty-five woolen mills and eight gas works; that this

does not include all of the plants as he has not had an opportunity to check up on all of them; (1953) that the majority of these plants are in New Hampshire; that you therefore start with the Merrimac as a stream highly polluted by sewage and industrial wastes, the control of which lies in another state, and the intake as proposed is immediately below the state line; that in the next forty years he cannot see it in any other way than that there will be a normal increase in pollution; that he thinks the Merrimac must always be a drainage artery and that it has always been so recognized; that such recognition has been registered by the Massachusetts Legislature in taking this stream out of the control of the State Department of Health within the limits of Lowell; that he believes that economic necessity requires that rivers shall be recognized as carriers of waste within certain limits; (1954) that it is his opinion that the present tendency in water supply is to go to the head waters of the stream because of the inevitable pollution in large rivers in their lower reaches; that this is indicated in numerous places by recent water supply developments; that he refers to the abandonment of the Passaic river by Jersey City, and the abandonment of that river by Newark; that Paterson, Passaic, Clifton and other towns in New Jersey are participants in the so-called Wanaque scheme in which they undertook major expenditures in order to enable them to get away from the Passaic river; that Albany has gone into an upland supply and abandoned the Hudson; that Hartford did not use the Connecticut river; that Lawrence has been trying for years to get rid of (1955) the Merrimac; that he thinks a large number of other cases could be cited, indicating the tendency toward the abandonment of polluted rivers in favor of upland supplies; that a responsible engineer would have to take into consideration the possible future development along a river such as those he has mentioned, in using them for a water supply; that he has to anticipate that industrial development will increase and recognize that at any time works may be located on the river which would result in phenol or other wastes in solution which would be difficult to remove; that within a month Philadelphia had

a terrible case of gas works waste in the Schuylkill river, which is one of the sources of Philadelphia's water supply; that the Merrimac projects stated by the Connecticut witnesses involve continuous diversion, storage, aeration, coagulation, filtration and chlorination; (1956) that his first criticism of the scheme would be that the storage in the Foster-Martin reservoir would not be more than fifty per cent effective under normal conditions; that due to its shape and the various bays and coves, the water would run through the reservoir without the volume becoming more than fifty per cent effective; that under certain wind conditions the water would pass from the inlet to the outlet in less than twenty days, and possibly in half that time; that the reservoir has an area of four and a quarter square miles; that, of the total area flooded, twenty-four per cent has an average depth of five feet; that of the total area flooded twenty per cent is swamp with a muck bottom, peat; that within a few days soundings have been made up there and without any effort gas pipes have been sunk to depths of twenty-eight to thirty feet, which shows the soft nature of the soil; that in the Foster-Martin reservoir it is proposed to store water forty feet or more above the normal ground water level of the Ipswich valley; (1957) that in his opinion a very substantial percentage of the water that is pumped to that reservoir will leak out through the ground by seepage into the Ipswich valley; that the effect of muck on the bottom of the reservoir will result in the development of micro-organisms which will give rise to tastes and odors very difficult to remove, and also probably to micro-organisms that will interfere at times with the filtering processes; that there has been a classic example of this in the Ludlow reservoir at Springfield, where the reservoir is not so deep as this but where the outstanding condition was the muck bottom; that this Ludlow reservoir, which was the water supply for Springfield, has been abandoned; (1959) that there will be a deposit of sludge from the Merrimac river which may further emphasize by decomposition this growth of micro-organisms and the development of tastes and odors; that under certain conditions water may get through

the reservoir from the inlet to the outlet in less than twenty days and possibly as low as ten days; that with one hundred per cent success in operation the plan will give an entirely safe water, outside of the danger of these organic tastes and odors which periodically will make the water unacceptable to the consumer; that a safe supply and an acceptable supply outside of those periods can be furnished; that, because of the particularly polluted character of the water, the project is open to the always existing objection of danger of breakdown in the filter plant, that such things do occur in the operation of filter plants and in the chlorination process; that within a month there was a shut down of ten days in Cambridge due to the breaking of a force main at the plant, entirely out of the control of the operator of the plant; (1960) that it is not possible to have one hundred per cent operation efficiency; (1967) that the continuous diversion of two hundred million gallons per day from the Merrimac is unthinkable, not only because of the industrial development below, but because of the stipulations which the War Department will set up; that with reference to the War Department action he has tried to test the Merrimac scheme on two bases: first, that the War Department would set up the same stipulation as they have on the Swift river, namely, that the diversion would be limited to flows in excess of approximately six tenths of a cubic foot per second per square mile of drainage area or in excess of a total flow to be limited to twenty three hundred cubic feet per second; that he has also tested the scheme on the assumption that a part of the War Department stipulation used on the Ware River project would apply, namely, that no diversion between June 15 and October 15 would be permitted, and only a diversion in excess of twelve hundred cubic feet per second during the remainder of the year; that twelve hundred cubic feet per second is used because of the fact that that (1968) is the amount of the continuous twenty-four hour flow necessary for firm power at Lowell; that it is the minimum flow of the river practically which, by utilization of the pondage above the Pawtucket dam at Lowell, will enable the mills to operate fifty-four hours a

week; (1970) that he does not believe that one can get the storage that is necessary in the Ipswich valley to develop the same yield from the Merrimac as can be obtained from the Swift, assuming that water is taken from the Merrimac only in excess of twenty-three hundred cubic feet per second; that, if water from the Ipswich valley is considered, another element is brought into the case over and above what enters into the Ware-Swift project, because in that case rights now allocated to cities in the Ipswich valley are being invaded, so that to obtain the gross yield from the Merrimac and Ipswich combined, the requirements of the Ipswich cities in 1970 would have to be subtracted, as well as a reasonable allowance for release down the stream; that the requirements of the Ipswich cities in 1970 is estimated (1971) at forty-one million gallons a day, and the release down stream at ten million gallons a day, a total of fifty-one million which should be subtracted from the gross yield of two hundred and twenty-three million, leaving a net of one hundred seventy two million on that combination; that assuming a diversion from the Merrimac river of all in excess of twelve hundred cubic feet per second, a yield equivalent to that obtained from the Ware-Swift project can be procured; (1973) that if no diversion is made except in excess of twenty-three hundred cubic feet per second from the Merrimac, the yield to the District will be only one hundred and seventy-two million; and that this assumes one hundred percent coordination in turning the water of the Merrimac river into the distribution system during the period after the Ipswich storage is filtered when the flow of the Merrimac permits continuous pumping under the diversion stipulation; (1975) that this high reservoir in the Ipswich is impracticable because it has such a large area of shallow flowage, because it consists of an elongation which is an enlargement of the channels for some ten miles upstream; that it is absolutely an unfeasible reservoir from a practical standpoint; that if one assumes that diversion must be intermittent from the Merrimac because of stipulations of a downstream flow, then very large storage is required, and there is no opportunity for such major storage in eastern Massachusetts;

that in order to get such major storage one must go to the western hills; (1976) that under the Merrimac-Ipswich scheme, the Ipswich reservoir would be filled each year in the spring; that in extreme dry years, in order to conserve the Wachusett supply, the Ipswich reservoir would be pumped down substantially to a point where large areas, two or three square miles, of wet soggy land would be exposed and where rank vegetation would grow during the exposed period—an ideal condition for mosquito development; that his conception of the damage is not limited to just the land uncovered or the land immediately adjacent, but that it would extend for miles and the entire surrounding country would be depreciated in value for habitation; that, if thirty day storage is kept in the so-called Hazen reservoir, the net yield to the district would be about (1977) one hundred and forty million gallons per day instead of a hundred and seventy-two million gallons per day; (1979) that, trying to view the problem as an engineer responsible for the actual carrying out of the work, it is his opinion that there is always the shadow of possible abandonment of this entire Merrimac scheme at sometime within fifty years, due to increased growth in the valley of the river; that there is no comparison as to the comparative quality and desirability of the raw water from this source and from the Ware river project; (1980) that it is entirely possible to get a safe water from the Merrimac river by the proposed treatment, assuming the highest grade of supervision; that there is a danger of breakdown perhaps at long intervals whereby there might be some water get by that would not be safe; that there will be during the summer season the continual probability of tastes and odors, which would make this water unacceptable intermittently to the consumer; that there is a particular danger of industrial wastes on the Merrimac, which, if they do not exist today, may develop at any time and which will produce tastes and odors which are very difficult to remove by treatment and which are simply emphasized by chlorination, due to the formation of chloro-phenols, which are even worse than the original taste and odor; that the Merrimac-Ipswich scheme

involves to a maximum degree the human factor, and compared with the Ware-Swift as an operating plan, is not in the same class and cannot be made so; (1981) that he is speaking of the Ware-Swift water with no treatment except storage in the Wachusett reservoir; (1982) that he has no hesitation at all in saying that he would chlorinate the Metropolitan District supply today if he were responsible for it; that he thinks that the Ware-Swift water would need no treatment other than chlorination.

He further testified (1982) that the Fifteen Watershed Plan as presented by Mr. Jacobs (1983) includes in the order of their proposed development, the filtration of the South Sudbury river, the Shawsheen-Ipswich development, the Lower Sudbury-Hobbs Brook development, the headwaters of the Assabet, and filtration of the Wachusett supply; that it is obvious that this project is to be substantially discounted by the multiplicity of sources and the resulting burden of co-ordinating them in actual use; that the project involves thirteen different new catchment areas; that it involves nine new pumping stations, widely separated and four filtration plans, widely separated; that of the water to be obtained in the Assabet development, about 80 percent is to be pumped and only the balance is procured by gravity; that the five Assabet pumping stations having two hundred fifty-three million gallons per day capacity must pump against an average head of ninety-two feet, which is a pretty high lift for raw water; that, in his opinion, no detailed analysis is necessary to show that this widely scattered small unit scheme is substantially discounted in value by that very fact; (1985) that this multiple unit project will give about seventy five per cent of the yield obtainable from the Ware Swift, which means that it would fail by some seventy million gallons a day to meet the requirements of 1970, and demonstrates the necessity of going to the Connecticut Valley or taking the balance from the Merrimac; that in figuring the yield from these sources he has not taken into consideration the future requirements of other communities in eastern Mas-

sachusetts outside of those provided for by the Ipswich and outside of those contemplated to be taken care of by the Metropolitan District; (1986) that if these communities made an additional future demand the yield will be correspondingly reduced and would emphasize that much more the necessity of going either to the Connecticut or the Merrimac for the balance; (1987) that in his opinion the yields estimated by Mr. Jacobs assume greater utilization of the flood runoffs in the Assabet, Shawsheen and Ipswich than would ever be practically possible where a large proportion of the water must be pumped; (1988) that the Lower Sudbury-Hobbs Brook reservoir suggestion contained in the fifteen watershed plan is absolutely impracticable; that Framingham is a large industrial town on the junction of railroads and is on the Sudbury river; that in his opinion the proposal to include the Lower Sudbury as part of this scheme is simply a very good illustration of how hard put to it the proponents were in order to build up the yield necessary in their endeavor to compare with the Ware-Swift; (1989) that this Lower Sudbury scheme must be omitted; that Hazen omitted it, and the water supply investigating commission, to which Mr. Hazen reported, recommended that it be dropped from further consideration; that if this Lower Sudbury scheme is omitted it reduces the yield to the District from the project to about fifty percent of that obtainable from the Ware and Swift and again emphasizes the absolute necessity of resorting to the Merrimac or to the Connecticut Valley to make up the supply; that the quality of the water on the Fifteen Watershed Plan would be less hazardous than the Merrimac; that there can be a safe supply obtained from this project up to the quantity he has named; that it will be a supply, however, which carries the necessity of continuous high-grade supervision, as it is open to all the hazards involved in the human factor; that, in his opinion, there will be tastes and odors periodically which would make the supply decidedly less acceptable than that obtained from the Ware and Swift; that this opinion is based on the assumption that the Lower Sudbury is included; (1991) that it is pos-

sible to pump water from the Shawsheen River into the head rivers of the Ipswich River; that he thinks there is better water propably in the Ipswich from the point of color; that the Ware-Swift waters with chlorination would be a decidedly better water from the standpoint of the water-works man than the Fifteen Watershed Plan with the complete treatment suggested by Mr. Jacobs; that he thinks that the multiple unit water problem can be made safe; that the risk or hazard is not as great with that supply as it is with the Merrimac; (1992) that he thinks that the conditions on the Ipswich and on the small shallow reservoirs on the Shawsheen and particularly the use of the lower Sudbury below the sewage disposal plants of Framingham, Natick, and Marlboro will at least result in the development of conditions resulting in periodic tastes and odors; that the supply would not prove acceptable to the consumers, at times; that there is no question but that the Swift River Reservoir site is one of the most magnificent sites that engineers have knowledge of in Massachusetts; (1996) that he is in favor of going into the Connecticut Valley watershed for water supply; that during the last 20 years he has not had any personal relation to the Metropolitan District; that he has knowledge of the situation the same as any engineer obtains by reading the joint report of 1922 and of the so-called Water Supply Investigating Commission of 1925; (1998) that he agrees that the Merrimac has ample supply of water for the immediate future but that that is not the problem involved in this case; (2000) that the supply to be obtained from the Merrimac would be sufficient for the usual and practical needs up to the year 2000; that he agrees that there is no doubt that the water of the Merrimac River could be used for the water supply of the Metropolitan District if necessary, provided it were properly filtered; that the clause "provided it were properly filtered" is a very large condition in that sentence; (2002) that the Metropolitan District has a very well operated plant; (2003) that if he had the responsibility of furnishing water to the City of Boston he would chlorinate it; (2004) that he doesn't

object to chlorination in the Merrimac supply but pointed out that it is liable to breakdown; that the same liability to breakdown that would occur in chlorinating the Merrimac would apply to chlorinating the Wachusett, except that in the case of the Merrimac a highly polluted water would be chlorinated and in the Ware-Swift project there would be a water which has been proved by its record to be reasonably safe without chlorination; that from his practical experience it is true that there come times when there is a taste and color in the water that must be gotten rid of but that they are more likely to occur when taken from shallow-bottom, muck-covered reservoirs, than they are when taken from the hills; that there ought to be a higher degree of care exercised in handling and delivering polluted water than is necessary in handling and delivering water from unpolluted sources; (2005) that there is very good supervision at Cambridge; that there was a shut-down there of 10 days within a month; (2006) that he has not examined the results of any bacterial analyses of water of the Ware and Swift Rivers; that at one time there was trouble in Akron, Ohio with the water supply; (2007) that a filter plant was built under his immediate supervision for the purpose of purifying the water; that the river used was the Cuyahoga, which had all the characteristics of a midwest water—high turbidity during floods—and was absolutely impossible to use in its raw state; that it looked like yellow mud, in the time of flood; that the filter plant has been what could be called satisfactory; that in connection with the Akron water supply, he arranged for the aeration of the water; that aeration helps sometimes in removing color and sometimes it doesn't help; that in Akron it has been used but very little; (2008) that he is not prepared to say whether or not it has been used satisfactorily when necessary to use it but that during the first year he thinks there was evidence that the aeration broke down some of the micro-organic cells and that the oils were brought into a more pronounced condition; that sometimes aeration is successful and sometimes not.

EDWARD L. WOODWORTH, called by Massachusetts, testified, (1928) that he is an attorney at law and a member of the bar of New Hampshire and Massachusetts: (1929) that he is counsel for various mills and the Boston and Maine Railroad; that he has examined the statutes and decisions of New Hampshire with respect to the flowage of lakes and ponds forming the head waters of the Merrimac River; that the Court of New Hampshire has declared that all ponds of ten acres or more are great ponds, and that the title to the pond and to the soil underneath the water from the high water mark is in the state; (1930) that as to those great ponds, in his opinion the law of New Hampshire is that the owner of the privilege at the outlet of such a great pond can use the pond for reservoir purposes and can draw it down certainly to low water mark, subject to the general principle that everyone who uses any sort of water right must make a reasonable use thereof in view of the other needs of other persons; that subject to the rather indefinite, but thoroughly established principle of reasonable use, which might under some circumstances permit the owner of the outlet to draw the water below low water mark, he would say that it would require a grant from the State to permit any substantial drawing down below low water mark; that the State, as the trustee of the water in the ponds, and its Legislature, as representing the people who are the beneficiaries, might agree upon even an extinguishment of the right; that (1931) the water should be maintained at least as high as low water mark, but that any injury that resulted from such drawing down below low water mark would require compensation to the persons injured; that with respect to the possibility of draw-down between high and low water mark and with respect to the use of water between high and low water mark and the extent to which that matter is subject to legislative regulation by the state, with or without compensation, his opinion is that the use of the water between high and low water marks is subject to reasonable regulation by a statute passed in 1911; (1932) that in his opinion the law is that the use of the water between high and low water mark is subject to reasonable regulation by statute passed in 1911.

MR. WESTON E. FULLER, an expert witness called by Massachusetts, testified (2017) that, with Mr. Barbour, he had worked out certain results with reference to the two schemes proposed by Mr. Jacobs—first from the Merrimac and second what Mr. Barbour called the "multiple unit project"; that all the results to which Mr. Barbour testified were the joint results of his work and that of Mr. Barbour—that he has heard all of Mr. Barbour's testimony and is in agreement in the conclusions and opinions to which he testified; (2018) that he agrees with Mr. Barbour that the 200 million gallons per day from the Merrimac was not feasible, due to the fact that there would be some restrictions placed by the War Department upon the use of the low water flow of the Merrimac River; that in his opinion the Ware-Swift development is very much superior to the Merrimac River, treated as proposed by Mr. Jacobs; that he believes the Ware-Swift represents about as good a water development as can be made, coming as it does from a high, sparsely settled section of the country, which it may be confidently expected will last for an indefinite period; (2019) that he thinks the future is to be considered even more than the present in constructing these water supplies, and he gives that opinion in the light of trying to get cities to develop a good water supply; that after cities have spent money in developing a poor water supply it is very difficult to get them to change; that in his opinion this opportunity to secure an unpolluted supply from a district which in all probability will not grow, in which the inhabitants will not increase, should never be neglected for the sake of taking a supply from a district on which the population is absolutely certain to grow, and which is out of the control of the State of Massachusetts; that he believes it would be a grave mistake to develop small supplies on the Assabet, the Shawsheen and the Ipswich, which are close to the Metropolitan District, and which are certain in the future to have large increases in population; that from the Ware-Swift project you get an unquestionably good raw water to start with—that it may be advisable to chlorinate it merely for additional protection,

although he doubts if that is really necessary; that the other supply (the Merrimac) can be made safe by the most careful purification methods, providing everything works as it is planned (2020) to work; that from his own experience he knows that filter plants do not always work as they are planned —that there are break-downs, that things happen, that there is always a chance of carelessness on the part of operators, and many other things may happen that make a polluted water objectionable when a good supply can be obtained; (2021) that he agrees with all the conclusions to which Mr. Barbour testified, whether or not he has been specifically asked about them, with the exception of one error, which he corrected; (2024) that waiving, for the present, the possible requirements of the U. S. War Department, the effect of the abstraction of something like a quarter of the flow of the river at low water from the Merrimac at Tyng's Island will be a very serious matter; that he believes it takes the best of the power away; that, in other words, (2023) it takes away the power which is continuous and can be used continuously throughout the year; that 200 cu. ft. per second diverted throughout the day means 600 cu. ft. per second or more in the working period, the water being used for only some 50 hours; that furthermore, under certain conditions it would be necessary to draw down the pond, which would cause a very heavy damage to the power as that pond is used to save the water during the dry period of the year, so as to use it during the day hours; that he believes that $5,000,000 is a low figure for damage to power on the Merrimac development, and that that is the minimum amount; that he is surprised that Mr. Uhl used a figure of 5 mills per kilowatt hour for surplus power, because (2026) it is not possible to obtain 5 mills in other parts of the country; that in Western New York around Cohoes, where there is an interchange, the value is as low as 1½ mills, 2 mills and 3 mills; that he remembers about the typhoid epidemic in Plymouth, Pa., as it is a well-known case, but does not remember the details; (2027) that he is quite sure they did not have a supply like the Ware-Swift—that it is possible for

an epidemic to come from a house on the watershed of a small reservoir; (2028) that such an epidemic is perfectly possible with a small reservoir where there is very little water compared to what enters; that a happening like this is not going to occur in a reservoir with a period of storage obtained in the Ware-Swift; that it is not going to occur with a long period of storage; that he does not think anyone can say today how long a storage period is necessary for the Merrimac water—that he believes most of the talk about the period of storage is based on the London experience, where they put water into a reservoir and leave it alone for a definite period; that his recollection is that the period is something like 35 to 40 days, at the end of which period they draw it out and filter it; that better results are obtained than if they put it in a reservoir and used it; that the London water is safe—that he has not heard anything to the contrary; (2029) that if the Ware-Swift as a water supply for Massachusetts was eliminated from the picture, it would be possible to get a supply from the Merrimac, which ordinarily would be safe; that this supply would be worse than that of Washington, D. C., because the river is much more polluted than the Potomac River; that they had storage before purification in Washington; that if there was furnished a 60-day storage of water from the Merrimac, and then this water was put through a rapid sand filter, then chlorinated, it would give Boston a safe water, if things work all right; that all over the country there are many river supplies, but that is a case of having nothing else that is better.

"Q. I am eliminating the Ware and Swift. If you had a section of the country like eastern Massachusetts, and you were in the same position that you would be in if you were on the Mississippi River where you did not have anything else to go to but the eastern supplies of Massachusetts, you could produce a safe drinking water for Boston, couldn't you? A. Under ordinary conditions I think you could, but I would says this—that because

most people have to live in tenements it is no reason why you should make everybody do so.

"Q. If you had your choice, where you could go to a supply that was very slighted polluted and one which was polluted, you would go to the one which was less polluted? A. I would go to the supply which was satisfactory in its original condition.

"Q. If people have to have a water for drinking purposes and cannot go to sources which are not polluted, you can take the water at their door and treat it so it will be safe for human consumption, can't you? A. Yes, you can do that under ordinary conditions, but there are the chances of its falling down."

That he believes that there is an extremely remote chance on the Ware-Swift development of somebody getting some typhoid germs in the water, and that storage and chlorination would eliminate danger from that; that it is the simplicity of operation of the Ware-Swift that insures the supply of being good quality at all times;

"Q. Mr. Warren: And the question in your mind is whether, there being no physical obstacle to getting a good water, there should be interposed some legal compulsion requiring the Metropolitan District to take a poorer water— is that about the question? (2031)

"The Witness: That is the way it seems to me. It seems to me it would be a great mistake to force a metropolitan district to take an inferior supply under the conditions which exist."

that his personal opinion is that the supply for Eastern Massachusetts ought to come from sources similar to the Ware and Swift, and these will be from the western part of the state; that such a possibility is in a period beyond 1970; that the tendency of the estimates which he makes himself, and that others make, is to over-estimate a little; that he believes the estimate for Eastern Massachusetts is a good one; that the supply may suffice only to 1970, but he thinks it would go a few years beyond; that if this water supply is planned for

1970, the plans for a new supply would have to start 10 or 15 years before, if the population increases as fast as it has; (2032) that if Massachusetts did go to those other tributaries of the Connecticut River and the War Department required Massachusetts to let down more water than naturally went into the Connecticut River in a dry season, conditions on the Connecticut River would be benefitted; (2033) that while there is no way of guaranteeing this release, the War Department has treated the State of Connecticut pretty well so far.

HARRISON P. EDDY, an expert witness for Massachusetts testified (2039) that he had done work on the Merrimac River for the cities of Manchester, Concord and Laconia or individual corporations within those cities; that while he was familiar with the lower part of the Merrimac River, he had never done any professional work in that immediate neighborhood; that he thinks there is a very serious difficulty in controlling pollution in the Merrimac River and in the Nashua River in both New Hampshire and Massachusetts; (2040) that the Nashua River lies largely in Massachusetts; that in Massachusetts where authority can be obtained for controlling the pollution, it is almost an impossibility to accomplish it; that he would cite his experience in the city of Worcester as an instance of this; that the City started sewer disposal works in about 1895 or 1896 costing perhaps a million dollars; that within the last five years another mandatory statute was passed in which the City was compelled to spend more money; (2041) that, as he has been over the Blackstone River below Worcester, it seems just as offensive and foul, if not more so, than it was when he went to work for the City in 1891; that (2042) the reason for this is because the disposal of sewage is the last thing that anyone has any interest in; that it is easy to get money for streets because the people see them and use them, but the difficulty of getting money and appropriations and support for sewage treatment is exceedingly great; that his firm built a sewage disposal plant for the City of

Fitchburg starting in 1914; that the plant has operated well but the industrial waste is still going into the river and in his judgment it is almost a practical impossibility to clean up that river; that the Merrimac River as a natural waterway is an enormous asset to the State of New Hampshire for industrial purposes, and that in his judgment it will always be used as an industrial stream; that it is inconceivable to him that the Merrimac River will ever be cleaned up in a sense which one would expect in order to make it suitable for water supply purposes; (2043) that the river above Tyng's Island is a series of mill ponds; (2045) that there is no question but that bacteria discharged from the sewerage system of Laconia or any of the cities lower down in New Hampshire would reach Tyng's Island in a virulent form; that the total population on the Merrimac River drainage area above Tyng's Island is 229,400 or about 58.4 persons per square mile; (2046) that the watershed up to Concord, New Hampshire, shows a large population per square mile; that in the balance of the watershed it showed a very different figure because it is up in the hills and mountains; (2047) that he estimates the total amount of domestic sewage emptied into the river is eleven million gallons per day in New Hampshire and five and one-half million gallons a day in Massachusetts; that these figures refer to domestic sewage; that at a very low flow of 500 cubic feet per second there would be 5 per cent sewage in the river water under present conditions and by 1970 he would expect there would be at least double that or 10 per cent; that in other words, at the present time there would be something like 2/3 of a teaspoonful of sewage in a glass of water; (2048) that according to Mr. Knowles' report in 1917 there were 116 industries on the Merrimac River above Tyng's Island; that a recent investigation showed a total in the same area of 75 industries engaged in work which naturally results in the production of liquid wastes; that the aggregate volume of wastes according to Mr. Knowles' report was 25,000,000 gallons a day in New Hampshire and 34,000,000 gallons a day in Massachusetts; that Mr. Knowles also gave the quantity of solids in

these industrial wastes as 1,000,000 pounds per day; that the proportion of industrial wastes in the river (2049) for 500 cubic feet per second would be nearly 19 per cent or, in other words, in a tumblerful of water about one-fifth would have been industrial wastes; (2050) that it is certain that the industrial wastes in the Merrimac Valley will at least double; that he bases this estimate on the fact that there is available a large, abundant supply of water for industrial purposes, which will become more scarce in the future than it has been in the past, and he believes his estimate is a conservative one; (2051) that the third source of information regarding industrial wastes was Exhibit C-34 which estimated the total population equivalent as 232,900 which he thinks is a very moderate estimate; (2052) that he believes that the establishment of a single industry upon the Merrimac River might well contribute as much industrial waste as has been allowed in this latest estimate; (2053) that the processes of self-purification go on very slowly in the winter time as compared to the summer; that the discharge of sewage and industrial wastes of an organic nature into the water in the winter time is like putting those organic compounds into a refrigerator; that where deposits of such materials are made during the cooler portions of the year, in the summer time when the temperature is higher, the entire accumulation of cold weather swings into activity and creates a very great demand on the natural purifying processes of the water; (2054) that the processes by which sewage and industrial wastes can be purified are many, but the efficiency of such treatment is very low; (2055) that it is not practically possible to obtain anything approximating perfection in the purification of the sewage; that "to produce a satisfactory water for domestic supply calls for the purification of the water rather than or in addition to the purification of the sewage and the wastes"; that he has estimated or considered the pollution of the Merrimac River at Tyng's Island from the point of view of offensive conditions; (2056) that he questions whether conditions at Tyng's Island, from the standpoint of human sewage alone are objectionable, because, first there is a measure

of self-purification in the river which tends to improve the situation, and in the second place the low flows are of very short duration; that a consideration of the dissolved oxygen in the river indicates that the river is approaching a condition in which it might be considered as being somewhat objectionable at certain times; (2057) that he is still considering human sewage alone; that if the industrial wastes are taken, as mentioned in Exhibit C-34, as double the quantity of sewage, then this leads to the conclusion that, with both human sewage and industrial wastes considered, the river is a grossly polluted stream from the point of view of a water supply; that the average of five samples from July 17 to November 16, 1923, indicate that the river is seriously polluted with sewage and industrial wastes; this average showed 57.5 saturation and the flow was 1795 cubic feet per second; (2058) that the records taken at the intake of the Lawrence filter plant, obtained through the State Board of Health, showing the B. coli index per 100 cubic centimeters from 1918 to 1929 were as follows:

1918	10,300
1919	19,400
1920	11,800
1921	19,000
1922	6,900
1923	7,200
1924	6,600
1925	5,700
1926	6,700
1927	4,500
1928	4,200
1929	3,400

(2059) that there is a decided drop in the records of B. coli tests since 1921 and that may be explained by the effect of some particular kind of industrial waste; that he believes that bacteria will reach Tyng's Island in virulent form; (2060) that he has the following conclusions as to the quality of river water at Tyng's Island: (1) the river is only moderately high in color; (2) at times of flood and storm it is quite turbid

but not seriously so; (3) it is heavily polluted with sewage and industrial wastes and intestinal organisms are certain to be present in virulent form; (4) at times it is likely to contain products from gas works and paper mills and in the future he thinks it is almost certain that such compounds will be present at times and be likely to cause trouble with purification processes; that phenol is the substance from gas works which gives water its disagreeable hospital taste and smell; that substances from paper making are very persistent; that in his judgment the Foster-Martin Reservoir will not be anywhere nearly as effective as the figures indicate because (2062) the natural current due to the flow is certain to produce a short time of detention for much of the water and at times the effect of wind is very likely to carry the water very directly to the outlet; that he has observed this effect which is frequently called short circuiting due to wind many times in bodies of water, for instance, in the water of Lake Ontario at Rochester; (2063) that in his judgment the following precautionary measures of purification would be required to make the Merrimac River as satisfactory as possible for use as a domestic supply:—he would use aeration at the outset and principally chlorination and the latter should be used all the time with some exceptions possibly. Then he would provide coagulation, sedimentation, filtration and finally chlorinati much of the time and at times post-aeration, and finally the correction of the corrosive properties by the introduction of lime in the final effluent; that he believes the difficulties of purification would increase with increasing pollution; that the character of the water is such that the growth of water plants, the algæ or plankton in the reservoir, would be very prolific and troublesome; that he had neglected to say that from time to time it would be necessary to use copper sulphate to keep these organisms under control; (2064) that other than the difficulties which he has intimated in the operation of these corrective measures there would always be the practical difficulty, due to human frailty, of having the works operated in a highly efficient manner all the time; (2065) that one of the

most spectacular illustrations of this which he knows about personally was at Detroit when there was apparently a reversal of flow or change in the current conditions which permitted sewage to cross the river and reach the water supply intake; that notwithstanding the fact that Detroit had a practically new filtration plant, this condition resulted in about 200,000 cases of (2066) intestinal disorder, yet the reversal of flow did not last more than five or six hours; that recently the Cambridge, Massachusetts, filter was shut down; that it is difficult to get information about lapses in purification plants because operators do not like to advertise them but that there are a good many lapses which constitute a serious objection to the use of a highly contaminated raw water for the supply of manufacturing water to any district; that the increase in growth of water plants in the reservoir will increase the difficulties of operation. (2068)

> "Q. What is your judgment with reference to the quality of the treated water for use as a domestic supply? A. I think it is possible to make what we ordinarily consider a safe water. The bacteria will be low usually; the intestinal organisms will be absent. If the water is chlorinated before and after filtration, that is a very good safeguard. Such storage as may be effective storage will help. (2069) Nothwithstanding that in my judgment it was a hazardous supply and one which is dangerous to adopt. If the District must use that water I think it can be purified so that as we ordinarily speak of it, it will be a safe water. I think there will be objection to it. There will be times when there will be tastes and odors but I should expect to find a condition resulting similar to that in Lawrence found by Mr. Knowles where the people objected to the use of the water, if for no other reason than because they know where it comes from. Now that has several effects. It has the economic effect which perhaps may not be material in this case, but it also has a health effect because frequently people buy bottled water thinking they are getting a safer water and yet they are getting worse than the one from the supply that they are shrinking from. . . . . Q. Well, taking all the condi-

tions into consideration surrounding this Merrimac River supply, how do you think it would compare with the present source if the present source were chlorinated? A. I think the present source would be distinctly safer, less hazardous and better. Q. That is with chlorination? A. With chlorination. Q. What do you think of the comparison of the proposed Merrimac water to the Ware-Swift supply without chlorination? A. Why, in my judgment the hazard is very much greater (2070) in the case of the Merrimac River supply. Ordinarily I think the Merrimac River supply will probably be as safe and possibly a little safer than the present supply without chlorination or the Ware-Swift supply brought in through the present works without chlorination because there is opportunity for contamination.

That he believes if the present supply supplemented by the Ware-Swift were brought into the Metropolitan District without going through Sudbury Basin it would constitute a very decided improvement; that Sudbury Reservoir is itself somewhat exposed to contamination and just before water reaches this reservoir it flows in an open aqueduct and is more or less exposed to contamination; (2071) that Sudbury water is (2072) very much better than the water from the so-called Lower Sudbury River as proposed by Mr. Jacobs, better than that water could possibly be; (2073) that the Ipswich River water itself would be a highly colored water and he would expect a very large algæ growth which would interfere with the purification process; (2074) that it is possible to make a water which would prove reasonably satisfactory from the Ipswich basin itself; that he thinks this plan (this is a discussion of the modification of the Merrimac scheme suggested by Mr. Kennison and Mr. Barber) with respect to the quality of the purified water and the difficulties of preparing water for consumption would be preferable to the Foster-Martin plan; that he thinks, however, there would be a serious hazard. "I should call it a hazardous water from a polluted supply much the same as in the Foster-Martin project"; (2076) that regarding the situation in the Ipswich River watershed and south of it, there is an enormous amount of through and local traffic, with

picnicking, roadside stands and all of the features which would tend to make it difficult to maintain the purity of the water in the basin; that there are a number of communities there which are growing and which in the future will grow very much more; (2077) that he believes that this Ipswich River water is very materially deteriorated by adding the Merrimac River water; that he believes the conditions are slightly better than they would be from the Foster-Martin project; that he has considered the development of the Assabet River; (2079) that of the whole Fifteen Watershed Project, the nine watersheds on the Assabet River are perhaps the best of any of the fifteen which are suggested as an alternative to the Merrimac supply; that there is very little swamp land on these nine watersheds; that it is rolling country and its natural condition is quite favorable to a moderately good water supply; (2080) that the very serious objection to it is the encroachment of the population both permanent and transient; that he thinks the water would have to be filtered and chlorinated without any question; that he has had supervision of the industrial waste disposal works of the Assabet Mills of the American Woolen Company, which are on the Assabet River, since 1913; that the wastes of these mills have been a source of serious complaint from the town of Concord, Massachusetts; that his firm has been able by various methods to control the pollution from their cloth and wool washing so that there has been no serious complaint; (2081) that the effect of the proposed diversion on the Assabet Mills would be likely to require the introduction of process water purification to produce a better water than they would receive if the water were not diverted and they would be certain to have to use an extreme degree of purification of their waste which they now avoid by the use of diluting water; that a compensating reservoir as suggested by Mr. Hazen would materially help the situation; (2082) that this compensating reservoir should have a capacity of at least 3,000,000,000 gallons; that the total amount of process water required by the Assabet Mills is about 6,000,000 gallons a day, and the volume required for the dilution of waste under present operation is about 30,000,000 gallons a day; that the Shawsheen Mills of

the American Woolen Company situated on the Shawsheen River just below where it is proposed to construct a dam as a part of the Fifteen Watershed Scheme uses (2083) between 3,000,000 and 4,000,000 gallons a day; that the industrial wastes are discharged into the sewers of the Town of Andover so that the proposed diversion would not enter into the problem of the disposal of industrial wastes; (2084) that it is possible to purify that water and turn it into water of ordinarily good quality; that he would not rank it quite as high as the upland area of the Assabet although (2085) it is possible to make a fairly good water out of it; that the taking away of the process water would shut the mill down; that at the present time the minimum flow is barely sufficient to meet their needs; that, referring to the South Sudbury project, it is feasible to purify that water and turn out a water of moderately good quality; that he would not rank it quite as high as the upland area of the Assabet, although it is possible to make a fairly good water out of it; that the water has a hazard attached to it due to its proximity to highways and settlements; that the Lower Sudbury development (part of the Fifteen Watershed Scheme) is a very unfavorable catchment area for a municipal supply; that it is subject to all the hazards of development and of transient population; (2086) that it has within it the sewage treatment plans of Framingham and Natick and also that for the City of Marlborough; that it is physically possible to shut these plants down and divert the sewage into sewers which run into Boston Harbor although the Metropolitan system is not designed to take care of this area; that the water in the catchment area including the sewage effluent would be very unfavorable for water for municipal supply; that if it must be used and the District is limited to areas east of the Connecticut River watershed there can be manufactured a safe supply from the lower Sudbury; (2087) that the watershed of the Shawsheen River is quite similar to that of the Ipswich in respect to the relatively large area of swamp land; (2088) that the watersheds are between two highly populated and increasingly populated sections, the one the cities of Lowell and Lawrence and the other Greater Boston.

Q. What are your conclusions relative to this project as a whole of what we might call the Assabet-Sudbury-Shawsheen-Ipswich Project or the Fifteen Watershed Project? A. Taken as a whole I think it is distinctly superior from the point of view of quality to the Merrimac, developed either with the Foster-Martin River or in conjunction with the Ipswich. I think it is an inferior source as compared with the Ware and the Swift or the Wachusett. I think it is a source (2089) which is going to be extremely difficult to maintain at anything approximating satisfactory sanitary conditions in the future. If Boston must use this water, I think it can be manufactured into what we ordinarily call a safe water. It is however a hazardous water from a more or less polluted source. But the pollution in my judgment is not so serious as that on the Merrimac River";

That he thinks it would be a relatively difficult project to operate; that it is a very difficult project to coordinate and utilize to the best advantage, but it is a possible source of supply; that he has considered the Swift-Ware project and thinks that this is as nearly a perfect catchment area as can be obtained in this locality; that he is not qualified to pass on the site as an engineering project; that the storage which is proposed would be very desirable; that the Swift River water has what he would call a moderate color and (2090) that the Ware is more highly colored; that if this water could be brought directly from the large Wachusett Reservoir into Chestnut Hill Reservoir, he doubts very much if chlorination would need to be considered; that the possibility of increase of potential contamination is not an objection to the Swift and the Ware; that he believes the present Wachusett-Sudbury supply an excellent one; that the water at the outlet of the Wachusett Reservoir is of excellent quality, possibly a little more highly colored than is desirable; on the other hand there is a residential development from the City of Worcester out toward this reservoir into the catchment basin now which constitutes a potential hazard; (2091) that the Sudbury reservoir is worse off in this respect; that he has made examina-

tions of the analyses of the water from Chestnut Hill in Boston after passing through the Sudbury Reservoir which indicate that this water is not as good as at the Wachusett outlet; that he has a rough method of comparing these several sources of supply in order to give a reasonably clear impression of their relative sanitary or hygienic merits and effects; that this method was developed in 1916 or 1917 by Mr. Theodore Horton and Mr. Eddy's partner, Mr. Chase; (2092) that this method was investigated by a committee of the New England Water Works Association, which reported the method; that he has scored the several supplies; first, with no storage—that is, the raw water, except that the Wachusett, South Sudbury, North Sudbury and Scituate he could not score that way because they are now stored; (2094) that the proposed Merrimac supply is distinctly inferior to the other supplies considered to supplement the present Wachusett Sudbury supply; that he thinks the Fifteen Watershed supply is distinctly inferior to the Swift-Ware but a better one than the Merrimac; that considering all of the present conditions and his conception of conditions of the future he thinks that the Swift-Ware is decidedly the most favorable from the sanitary point of view and the point of view of acceptability to the consumers; (2096) that he wishes to point out that Mr. Knowles' report (to Lawrence) which has been referred to, relative to industrial wastes in the Merrimac, was made during the War; (2098) that he believes an engineer should give weight to popular opinion in the source of a municipal supply for at least two reasons: (1) because the public is opposed to the water, either because of its color or its odor or because of knowing that it comes from a polluted source, and the tendency is to use other water, bottled water, and I think I did point out yesterday that it has been found in a number of cases that bottled water is actually inferior to the municipal supply; that is the sanitary reason; and (2) the financial reason: that, as was pointed out in Mr. Knowles' report of 1917, when he found that the people of the City of Lawrence were paying at least $70,000 a year for bottled water; that with a city situated as Boston is, a center to

which travelers come, many people inquire with reference to the quality of the water, and that if the local impression is unfavorable it is decidedly detrimental to the interests of the city; that he should give and has given a number of times consideration in that manner; that it is quite common for municipal supplies to be taken from rivers and lakes which receive sewage and industrial wastes; that Cincinnati, Louisville, and a number of smaller cities (2099) have taken water from the Ohio River; that the Ohio River drains on enormous area and the concentration of pollution at Cincinnati is perhaps a third or a quarter of what it was in the Merrimac some ten or fifteen years ago; that the more highly turbid waters of the central west are more readily purified bacterially than the clear waters are; (2100) that cities in the middle west take water from the Great Lakes, Cleveland, for instance; that Chicago takes more or less water from Lake Michigan; that notwithstanding the great effort which Chicago has made to keep the sewage out of the Lake the water is somewhat polluted; that the performance of the purification plant in the Ohio Valley has brought about a very great improvement in the quality of water supplies and "I think the advance in purification of polluted waters is largely the cause of reducing the prevalence of typhoid fever in the country. It is not by any means the only cause, but it is an important cause;" that he considers it advisable to go to an upland source when it is available, a practically unpolluted source, because of the hazard of manufacturing a municipal supply out of the raw product which itself is (2101) polluted and is dangerous; that the water supply of the City of Rochester is an instance of this, where the city took water from Lake Ontario into which the sewage of the city was discharged and he was one of the Commission which recommended that the City go to an upland supply in Honeoye Lake; (2102) that the Ontario water is vastly superior to the Merrimac from bacterial counts although in a lake water there is the hazard of sewage being carried intermittently by the wind to the water supply intake; that he thinks it is reasonably necessary for Massachusetts to go to the Ware and Swift River for a supply for Boston.

"Q. Taking into consideration your experience do you make that answer even though the water from the Merrimac can be made safe? A. Yes, I do.

(2103) that Exhibit D-27 is entitled "Reasons for Favoring Uncontaminated Raw Water Supplies with Particular Reference to Introduction of Purification Processes"; (2105) Exhibit D-28, being the scoring of the water supplies of the various projects, was introduced; with reference to this system of scoring, about one-half of the total possible score depends on the initial character of the raw water before taking; that it is based upon three things: population per square mile, not connected with sewage; second, sources of direct pollution; that is, population served by sewers; third, sources of direct pollution where sewage treatment is introduced and the sewage is treated before it is discharged into the river or lake; that, so far as the part of the scoring from which you start is concerned, that is the initial character of the raw water, in any one of these three things, it is entirely irrespective of any subsequent treatment of the water and irrespective of the character of the water delivered to the consumer; (2107) that an engineer ought to have regard for the future as well as the present moment in picking out a water supply and that this fact cannot be shown by analyses; that regarding the recommendation that Cincinnati continue its policy of discharging its sewage into the Ohio River and that particular attention be given to constructing outlets so as to secure a thorough mixing of the sewage with the river water, he would make the same statements today under the same conditions; (2109) that in the same report the witness stated; "While there may be sentimental objections to the discharge of sewage into this river from which a domestic water supply was taken, such objection should not prevail against reason and experience which demonstrates that this water, when properly treated, is an acceptable and potable water for domestic consumption;" (2111) that he also states in that report "the number of bacteria removed in the settling reservoir by the process of coagulation and by mechanical filtration is so great that scarcely one per-

cent of those present in the raw water appear in the effluent from the filters; whenever deemed necessary the effluent from these filters can be further treated with calcium hypochloride, which appears to destroy practically all of the remaining bacteria. A careful study of the bacterial tests of the water treated at the Cincinnati water filtration plant indicates that this plant is capable of successfully handling any water likely to be delivered to it under present conditions;" that most of the cities along the Ohio River discharge their sewage into the river, and that this water when properly treated is a safe and potable water for domestic consumption; that (2110) the cities along the Ohio cannot continue indefinitely to grow and discharge their sewage and industrial wastes into the river without producing a degree of contamination which will overtax the capabilities of the water treatment plants; that at present these plants are not overtaxed and the data on hand does indicate that the health of riparian communities is injured by the use of the river water where a reasonable effort is made to protect the water supply by efficiently treating the water, a measure which should be adopted even if sewage and industrial wastes were not discharged into the river; that Cincinnati and Louisville (2111) did have storage of their water in 1912 and 1913 and that (2113) the result obtained by something like five days storage on the fill and draw principle with two reservoirs produced an excellent result from a bacteriological standpoint; (2113) that forty or fifty years from now it may be that we won't drink any water unless it is scientifically treated; that he would say that is almost the case today; (2114) that the witness built a plant at Greenwich, Connecticut, which comes the closest to a supply which has pre-aeration,—pre-chlorination, storage for sixty or ninety days or thirty, coagulation, sedimentation, filtration, chlorination, and post-aeration; that all that is practically all that human nature can possibly do; (2115) at the present time to make polluted water safe; that he thinks they are getting very good water in Greenwich.

GEORGE W. FULLER, expert witness for Massachusetts, testified (2123) that, as to the *relative desirability* of water from a pure source, as compared with a source from which water requires purification, the source which is pure is preferable to the source which relates to pollution; that the reason of that goes back to his training at the Institute of Technology in 1888 and 1890, when he was a student in the classes of Dr. Brown and Dr. Sedgwick, chief chemist and chief biologist and chief bacteriologist, respectively, of the Massachusetts Board of Health; that it was a time when the so-called germ theory was known to a few of the leading scientists, but was not widely known even among the medical profession and those interested in public health matters; that he was taught in the Institute that pure water was better (2134) than purified water, and it was mentioned in the class room that it was quite a similar situation to dealing with human character, and the statement was made that innocence is better than repentance; that he had a chance to see that viewpoint set forth very clearly in his days in Germany, in and around Berlin, where they had those epidemics of typhiod fever, and where the medical profession made a very pronounced stand against the engineers who were seeking to filter certain ground water supplies in order to gain continuance of the surface water supplies rather than to get water from an underground source; and that was a marked feature in that viewpoint of the water works people, both the viewpoint of the medical people, who were sitting in the reviewing capacity, and also the engineers; that it was accentuated two or three years later when an outbreak of cholera occurred at Hamburg, which had a great deal to do with the development in this country, and which was really the basis which caused the agitation, consideration and final adoption of a program for the filtration of the Merrimac River; that it was the best they could do under the circumstances, but it was pure water rather than purified water that was the prevailing view in this country, in Massachusetts, and in Central and Western Europe; that an upland, gravity source of supply is preferable to a source receiving domestic and

manufacturing (2135) waste from a populous valley; that the element of cost ought not to be a factor within the range of negotiable limits of cost; that by negotiable cost is meant that a water supply which is not satisfactory to a community causes people to spend relatively large sums of money for bottled water; (2136) that the available barrier or means of defense available to water supply engineers as a measure for offsetting the pollution of public water supplies are:

(1) Avoidance or diversion of pollution at source.
(2) General control of domestic wastes by patrolling watershed.
(3) General control of industrial wastes by patrolling watershed.
(4) Treatment plants for domestic and industrial wastes.
(5) Self-purification in streams, lakes, or storage reservoirs.
(6) Water filtration, including coagulation.
(7) Water chlorination alone or combined with filtration.
(8) Algicides to destroy microscopic growths, such as algae and the like.
(9) Aeration.

that there are weak links in each of these barriers in each instance except perhaps the first, where you may get a ground water supply (2137) from deep wells; that there are also a few instances where waters are obtained from completely uninhabited watersheds such as the Birmingham watershed in the midland of England; that excepting this first instance you deal with the human elements in all of the rest and that they come into the picture with various degrees of intensity and with various degrees of frequency; that in regard to patrolling by policemen in respect to domestic wastes, there is a great deal that can be done by directing people to see that privy vaults are not only installed, but are used; that in regard to industrial waste, patrolling is very helpful but it is less successful than in the case of domestic waste because of varying load factors; that the patrolling system is subject to human weakness and

(2138) while the human element can be corrected by changing patrolmen, this situation is not entirely controllable by the men in charge of the watershed protection no matter how efficient a particular man may be; that is the difference between theory and practice; that in the case of sewage disposal beds, he knows of instances where holes were put through filter beds to an under-drain so that the sewage would go down through the surface and make an exit; that (2140) it is difficult to get industrial wastes under thorough control; that on the Merrimac River there is marked purification in the various mill ponds from Lowell up; that while there may be a removal of from 90 to 95% of impurities at certain times in the year, there will come times when the flood will not only move quickly through the mill ponds, the industrial and domestic waste entering the river, but they will (2141) sweep up the accumulation of impurities from the day or a week before, so that at some point like Tyng's Island there would be more impurities in the Merrimac River water than would come from any average condition as to the volume of waste and average flows; that regarding filtration and coagulation, there are elements which may constitute weak links—the fidelity of operation of the attendants in the amount of chemicals which they apply to match up with the quantity of water is apt to cause difficulty; that (2142) it is difficult to put in the proper quantity of chlorine to prevent or kill microscopic growths because on the one hand with too small a dose there is not a creditable performance in killing off the objectionable bacteria, on the other hand with too large a dose there are created objectionable tastes so that men are rather inclined not to over-dose and sometimes they under-dose; that aeration will do a great deal to cut out objectionable tastes but there are traces of oils with unpleasant tastes which are broken by aeration; that "speaking generally of this list of barriers, they are all powerfully helpful, but there are none of them fool-proof; they all have weak links. The water purification plant seeks to use them as advantageously as it can, but just because they are part of a water supply project it is not correct to say that the effects will at all times be that which it is theoretically possible to

state"; that it is a fact (2143) that the gas house wastes at Manchester, a city of 80 or 90 thousand people, are going into the Merrimac River and that those phenol wastes, certain products from gas house wastes, will combine with chlorine and will produce a so-called medical flavor in the water; that this is bothersome and interferes with the suitability of a good many supplies in the minds of the people; that the most serious thing in regard to this Merrimac River water supply is the fact that (2144) there is a wood pulp mill in the Town of Lincoln, New Hampshire, some 114 miles above Tyng's Island which is turning out about 74 tons a day of cellulose wood pulp; that the dry bases and other wastes of cellulose produces a black and bad behaving product which when present in sufficient amount will interrupt and prevent the action of coagulants in purifying the water; that this is a thing which might explain what Mr. McCarthy said in regard to inability to coagulate the water of the Merrimac River at Lawrence; (2145) that a similar waste from a wood paper mill makes the water at Richmond, Virginia, 240 miles below, incapable of coagulation; that that to his mind is the weakest link of any performance of any projected water purification plant in the Merrimac valley; that (2146) in discussing industrial wastes he has found very striking variations which lead him to be very cautious about drawing too strong conclusions about what you will find on any particular day or year; that (2148) the people in charge of purification have to adopt different methods to meet the varied types of industrial wastes; that

> "you would have to adjust your treatment procedures to put up factors of safety theoretically that would be adequate to deal with the waste products you would get at any one time. In other words, it is the weak link in the chain that counts, and your process—your procedure—ought to be strong enough so that there will be no weak links. And by that I mean to get a process that will do the trick every day in the year and not have it break down for three or four weeks, as Mr. McCarthy was telling about the other day—three or four consecutive weeks—when you do have something that causes the coagulation of water, for instance, to go wrong."

"Q. Now, the wastes in the Merrimac Valley found at present necessarily are no criterion of the wastes in future years? A In my opinion they are not. Any proposition that deals (2149) with a water supply from now on to 1970, you cannot take too literally the records of analyses of observers as to what comes in from industrial plants and draw conclusions which will be a safe guide for that which may be expected during the next forty years. That is not a safe thing to do.

Q. From an administrative standpoint, what particular weaknesses, if any, do you see in keeping wastes under reasonable control with regard to pollution of the Merrimac River supply? A. Well, from the standpoint of a Massachusetts project—a Metropolitan District project—there is no jurisdiction by any Massachusetts authority in any other State and, in fact in this particular state, since my own contacts in 1890, the Merrimac River and the Connecticut River were exempted from the jurisdiction of the Massachusetts State Board of Health under the Act which created its power to control the purity of inland waters. I think that is still in effect but you will have to ask somebody else about it. That is the understanding."

that (2150) a water supply project having the Merrimac River at Tyng's Island as its source ought to have 60 days effective storage which will be actually free from the readiness with which water sometimes comes from the inlet of a reservoir to the outlet; (2151) that the fact that Mr. Kennison's plan had only one reservoir is a weakness from an operating man's standpoint; that in order to put these paper mill wastes on the basis of definite control, it would be very important to provide two storage reservoirs which could be pumped into in rotation, and that the water in one basin would actually be retained for say a period of 60 days;

(2151) "Q. In your opinion, how does the quality of the Merrimac water, from Tyng's Island, after it has been stored and purified so far as practicable, compare with the water of the Swift River after the latter has been stored and chlorinated? A. It is inferior.

Q. How does the Merrimac water, treated as I have stated, compare with the Ware-Swift water without filtration of the Ware-Swift? A. I consider it inferior.

Q. How does the Merrimac water, treated as I have suggested in the previous questions, compare with the Ware-Swift water, if the Ware-Swift water has neither filtration nor chlorination? A. That is somewhat debatable, because personally, I believe the water coming from the Wachusett reservoir ought to be chlorinated, as a matter of precaution, not that the vital statistics or the analysis show that it is particularly necessary. (2152) I am rather puzzled also to know just how to answer that, in that if you can get the effect of these wastes that I have been speaking about, these pulp mill wastes and these phenol wastes, under control by a sufficiently large storage reservoir, that is one thing, but if you are going to have the breakdown of the coagulating that makes an element of risk, and I do not know what the future may bring as to other wastes of an industrial nature which may make a disturbing influence. If everything went well with the Merrimac project, why, I should say that it would compare very favorably with the unchlorinated, unfiltered water from the Wachusett reservoir receiving the Swift and Ware water, but that question of creditable performance year in and year out, day by day, on the Merrimac River, is subject to debate in my mind and is a serious question."

(2152) that regarding his views with respect to the Merrimac and Wachusett reservoir scheme in 1895, he knows a great deal more about the shortcomings of purification processes than he did in 1895, although he has had a great deal to do with purifying arrangements for public supply where they cannot get water supplies from unpolluted sources; that the improvement (2153) in purification arrangements applies particularly to the use of chlorination; that more is known about trouble from phenol and paper mill wastes; that a pure source is decidedly preferable and within the range of cost is certainly the thing to do; that (2154) he has found a general antipathy on the part of the public towards the use of water from highly polluted sources; that he considers it appropriate for the Massachusetts authorities to attach decided importance to such a view; that on the question of allocation of sources of water

supply, it is customary for recognition to be given to the needs of industries and small communities in the general locality from which there is proposed to be derived a water supply for a large city or water district; (2160) that from a practical engineering standpoint Boston should go to the Ware and Swift for its supply, having regard of all of the circumstances;

"THE MASTER: I would like to know directly, in your own way, what you think of the Merrimac River supply for the Boston Metropolitan District.

THE WITNESS: I think it is a very poor one, I find it has weak links that you could not control at all times, and when those links give away you are going to give them unsatisfactory water.

(2161) THE MASTER: Looking at the future, 30 years ahead, and considering the Merrimac with reference to that feature, what do you say?

THE WITNESS: Well, I think that it becomes then less and less desirable because here is a valley which has been devoted exclusively to various industries, which has an established labor market, an established set of facilities for mills and waterpower, and it seems to me it is bound to grow, that labor market is not going to go by unoccupied, and what those particular waste products may be, I don't know. Therefore, there is a question of doubt in my mind as to whether you can get a suitable water supply from the Merrimac River. But I am not looking at that, your Honor, from a standpoint of what happens within 60 or 90 or four months or six months storage reservoirs, but what will happen when those reservoirs are not behaving well and you get these slugs and paper mill wastes or other trade wastes washed out from behind these mill dams, and getting down to a point where they will actually overtax the facilities which are now available for purifying the water. In other words, it is not the average, ordinary, every day problems of treatment works in connection with storage reservoirs receiving water from the Merrimac River at Tyng's Island. It is a question in my mind what are those weak links when you got

a breakdown in the process and you give the people, by getting objectionable tastes and odors, water that is uncoagulated, in getting it markedly unsatisfactory to the consumers of the Metropolitan District, and I don't believe it is possible for anyone to say that they can be reliably treated. That is exactly the point that I want to stress in regard to these weak links, these lacks of performance of the human element, the lack of fidelity in human performance when the sleepy man at 3 o'clock in the morning lets things go wrong, the lack of jurisdiction in New Hampshire; obviously the industrial establishment is going out in trade which will let them use their industry to advantage. They are not going to control those wastes as a thing, practically speaking, that is reliable.

THE MASTER: You don't disagree with the witnesses who have testified that from a scientific view it is entirely possible to make a wholesome water out of the Merrimac flow?

THE WITNESS: Well, as a sunshiny day problem when everything goes fine, I will say I do agree, but I don't think that enough significance has been attached to the weak link when the stormy and bad-acting periods come."

J. WALDO SMITH, an expert witness called by Massachusetts testified (2165) that from 1905 up to the present time he was connected with the Catskill Water Supply Development for New York City, for the first 17 years of that time as Chief Engineer and since that time Consulting Engineer; that he had charge as Chief Engineer of that Water Supply; (2170) that in the spring of 1920 he was asked by the Department of Health of Massachusetts to take the place of Mr. Frederick P. Stearns as Consulting Engineer; that Mr. Stearns died in the latter part of the year 1919; that he is familiar in a very (2171) general way with the sources of possible water supply in the Commonwealth; that he has given consider-

able attention to the available sources of supply for the Metropolitan District; that the Metropolitan District has been the best district they have ever had; that that was due to Mr. Stearn's very broad foresight back in 1895, when he gave it such an extensive study; that Mr. Stearns was very capable and laid that district out with a broad policy which has been consistently followed; that the witness thinks that this is the reason why the Metropolitan District has been so successful; that since the appointment of the Commissioners in 1926 he has been consulting engineer of the Metropolitan District Water Supply Commission; (2172) that with reference to the size of aqueducts, dams and reservoirs, his experience is that he has never known one to be built too large and that in a great many instances they are not large enough; (2173) that he approves of the size of the aqueducts as planned and partly built by the Commission; that a gravity supply is better than pumping in a great many cases; that he does not think anyone would pump a supply if they could go to a gravity supply; that they would be willing to pay a great deal more money to get such a supply; (2174) that he would go to an uncontaminated supply with a system that could be developed within a reasonable cost, rather than to rivers carrying considerable quantities of sewage pollution and industrial wastes; (2174) that after what has been said by both the plaintiff's and defendant's witnesses in this case, he would not dream of wanting anything but an upland supply where the water was the best that could be obtained within reason; that he doesn't think there is any comparison between the Merrimac River on the one hand and the Ware and Swift Rivers on the other hand as a source of supply; (2175) that he would not want the Fifteen Watershed Scheme and that he would not give any attention to it; that he would turn down the Merrimac; that every time this water question has been up they have viewed the Merrimac River; that Mr. Stearns went through it in 1895 with a fine-tooth comb; that the Joint Board did the same thing with the same result; that another Board turned it down also; that about the same procedure was gone through

with the Assabet; that he approves what was done; (2176) that no other conclusion could be arrived at that he could see; that he regards it necessary from a practical engineering standpoint for Boston or the Metropolitan District Commission to go to the Ware and Swift for its supply; that having regard to all the circumstances and all the suggestions that have been made here of possible other sources; that everything that he has heard in this case has made him more strongly of that opinion.

Mr. Smith further testified that if the Ware and Swift could not be procured it would be necessary to get water in the eastern part of the State; (2177) that as to the size of the reservoir and of the tunnels the Joint Board recommended that they be built very ample in size and if required at some later date they would also take care of additions to that supply; that the Ware and Swift Reservoir site is very unusual; that nature has been very generous to that site and if there was only rock under the surface of the ground about 125 feet deep where the dam is to be, that would have made it absolutely ideal; that there is no pollution and the character of the soil and the topography and everything is such that a wonderful reservoir can be made, which will hold almost any quantity of water; that it is of such a nature that the construction must be done all at the same time; that they cannot go there and build part of these dams with any economy and at some later date get all the equipment and everything back to go on with the dam; (2179) that he might have said that the Commission might be criticised for the size of the construction were it not for the fact that it was the Commission's intention to take other waters of other rivers tributary to the Connecticut River, but that he does not remember saying that those structures were designed to be built to take care of more water than was immediately necessary; that this very small increment of water from the Ware and Swift Rivers that must be diverted will be so small that there is no method of measurement that has ever been devised that will show a difference in the channel of the Connecticut River before and after that diversion; (2180) that as to the dissolved oxygen, it is just the same thing; that

by 1970 there is no reason why other people should not go to the Swift Reservoir and get their water; that sometime or other Hartford or some city will put a pipe line up to the Swift River and have some of that water; that by 1970 the four States interested in the River—Vermont, New Hampshire, Massachusetts and Connecticut will sit around a table and consider this; (2181) that taking water from other tributaries of the Connecticut River after the Ware and Swift were taken was considered but that the witness did not say that he contemplated it; that the other water which could be gotten into the Swift would be the Millers, Deerfield, Westfield and the Quaboag, all of which are tributaries of the Connecticut; that these are ones which must be the next stop in the development of the Ware and Swift; that the Swift River could be made large enough to take care of the Metropolitan District and also the City of Hartford, if waters were diverted from the above four tributaries; (2182) that he thinks the Metropolitan District could feed other places if needed; that it is the best reservoir site that he has ever seen but that he has seen better dam sites; that the construction of the dam is perfectly practical and will have a perfectly satisfactory result.

THE LAWRENCE WATER SUPPLY AND QUOTATIONS FROM MORRIS KNOWLES' REPORT TO THE LAWRENCE WATER COMMISSION, 1917

It was agreed that quotations from the above report could be read into the record and they were so read in. They are found on pages 1511 to 1527, inclusive, of the transcript of evidence. Certain portions of this report are inserted in this joint abstract, as follows—

> (1511) "As a source of water supply the Merrimac is grossly polluted now, and will probably continue to become more polluted as time passes. Under present conditions its purification is incomplete and is attended

by certain lapses, which at numerous times in the past have reached a disquieting if not a dangerous stage. Although this supply can be artificially treated and purified so as to be perfectly safe to drink, the weight of disfavor against the stream as a source of supply has become so great and so real as to actually obliterate any economy in its use.

We therefore recommend that the Merrimac River be abandoned as a source of water supply for Lawrence."

Page 7. (1512) "In the same year (1887) the Merrimac River was declared an open sewer by the state legislature."

"Shortly after this there followed a most noteworthy series of typhoid fever epidemics on the Merrimac River."

"It was noticed and remarked that the outbreaks of the disease always followed those at Lowell, and with increased intensity."

Page 7.

"This phenomenon recurred in the late fall and winter months, year after year, with unusually severe epidemics in 1881 and from 1887 to 1891. Literally hundreds of Lawrence people died from the disease during these years" . . . . "The more intelligent citizens generally boiled the water for drinking purposes, or used various spring waters" . . . . "but the situation gradually grew from bad to worse." (1513) "Attempts in 1904 to purchase water from neighboring towns were without avail, and it appeared that reversion to the deadly raw river water was imminent."

In summing up the history and development of the water supply of Lawrence, Mr. Knowles makes note of several salient features. He states as follows:

"Salient Features: To the unprejudiced observer, three facts stand out strikingly, if somewhat paradoxically, in a study of the history of Lawrence's water supply.

FIRST: The consignment of the Merrimac River to the status of an open sewer, by the State Legislature of 1878. The importance of this Act, lies not only in its direct consequences, but in the index it gives to public opinion concerning the quantity of the water,—in short—to the reputation of the stream and wisdom of using it as a source of supply.

SECOND: The tremendous good achieved in Lawrence by the introduction of the processes of filtration, as a safe-guard against the infected waters of the Merrimac River.

THIRD: The long-standing and increasing antipathy of the public against continued use of the existing source of supply, regardless of filtration—efficacious or otherwise.

Page 4 (1515)

"The volume of sewage poured into the river is enormous, and it is computed that at average river stages there is one gallon of sewage in every 52 gallons of water flowing past the City of Lawrence." Page 5.

"Diagram C, being the result of a chemical and bacteriological survey of the river from Lawrence to the State line, shows the effects of this pollution in a graphical way. The unmistakable marks of heavy sewage pollution are shown throughout its course, as one would expect, but the diagram shows in addition the remarkable recovery from the added pollution at Lowell, between that city and Lawrence. To be sure, the river is somewhat more polluted at Lawrence than at a point just above Lowell, but the measurements show that the difference is not as great as one might expect. Incidentally the diagram shows in a striking way the beneficial effect of settling in the large reservoir created by the Essex Company's dam. The surveys were made during times of low to average discharge in the river, so that stream velocities were sufficiently low to permit the action of sedimentation and time to become manifest.

During the dry period it requires about 2½ days for the sewage of Lowell to reach Lawrence; during aver-

age flows it requires from 30 to 36 hours, and during flood flows it requires *only 2 hours for Lowell sewage to reach the intake of the water street pumping station.*

From the angle of our present problem, namely Lawrence's water supply, the lessons to be (1517) drawn from the data of Diagram D are more or less obvious. From it we see that ever increasing loads are being thrown upon the water purification works at Lawrence, which in turn must demand an increasingly effective purification if the quality of the supply is to be maintained at a safe standard. That a part of this purification may be accomplished by treatment of the tributary sewage does not invalidate this conclusion.

(1520) Aesthetic considerations which have to do with the reputation of the water supply, are important to all of us, particularly to the more intelligent. One likes to feel that his drinking water supply is beyond reproach in addition to its satisfactory appearance and apparent harmlessness. The attitude is traditional, being grounded in the early history of civilization. During its evolution, society has had to learn through costly and often fatal experience that unclean drinking water is a dangerous thing, although the causes for this fact remained a mystery until the last part of the last century. And, although modern science has been able to rid polluted water of its curse, by removing its infection, and making it safe through filtration, as yet it has not been able entirely to destroy the repugnance toward the drinking of a water *known* to be from an unclean source.

In the foregoing chapters, we have remarked some of the manifestations of the antipathy of Lawrence people toward their water supply. We have seen that, contrary to experiences with filtered supplies elsewhere, this antipathy has grown rather than diminished. It seems to follow, therefore, that the unpopularity of Lawrence's water supply has to do with something more subtle than slight physical disqualifications; otherwise custom and usage would have overcome the objection."

(At this point Mr. Knowles gives several illustrations of public opinion concerning the matter of taking water from the

Merrimac River. He devotes four pages to quotations from various newspapers in support of his contention that the people of Lawrence do not want water from the Merrimac River under any conditions even though it be filtered. A typical example of this is the quotation from the "Eagle" of August 11, 1905, which says:—)

(1521) "There would seem to be no need of haste in constructing a new filter. The people of this city do not want Merrimac River water for drinking purposes even though it be filtered, and the effort to secure some other means of water supply should not be abandoned just yet."

"At present, however, the pollution of the Merrimac River itself undoubtedly is the strongest element affecting public opinion. Since direct ill effects from the use of this water are not known to exist, it follows that antipathy to the Merrimac is largely an aesthetic matter, or one having to do with the appearance, taste and odors of the filtered Merrimac supply. Plates 11 and 111 giving views of the Merrimac River a short distance above Lawrence, illustrate the thing which is undoubtedly at the bottom of the public mind in its conception of the Merrimac supply."
(1521)

"The various pollutions and *nuisances* shown in these photographs are comparatively unimportant in proportion to the vast quantity of sewage discharged into the river at Lowell only a short distance above. These particular instances may be even unknown to a large percentage of the people in Lawrence; yet nevertheless they characterize the thing that is repulsive to the Lawrence water consumers, whenever they think of the matter at all, have some such picture of the source of their (1522) water supply before the mind. Science may characterize such objection as absurd, and modern sanitary practice may and can offer means of overcoming much of the physical and chemical nature of the *pollution* but it nevertheless remains that these objections are entirely human, and not readily to be gainsaid. Moreover, it is generally recognized among sanitary scientists and engineers that "Innocence is better than repentance", applies as well to a water supply as it does to a course of conduct."

"A Measure of Dissatisfaction.

The value of an enterprise can often be estimated from the success of its competitors, and remarkably enough, perhaps, such a criterion of worth is at hand, ready to be applied to the Lawrence water supply. We refer to the "spring" water business in Lawrence.

There are very few private wells or springs in use in the city of Lawrence. Besides the municipal supply, however, Lawrence has still another source of water supply in the various bottled spring and well waters which are sold throughout the city. These waters come from sources which lie largely outside the city limits, and are peddled from house to house by some 15 different dealers at prices ranging from 3 to 5c. per gallon, or at an average price of 3.9c. per gallon. The enterprise is of large proportions, so large in fact that it may be considered an important rival to the municipal supply. The total amount of spring water business in 1917 in Lawrence amounted to only a little less than $70,000.00 or 55 per cent of the average annual revenue from all water consumers, of the Water Department itself.

That this state of affairs is entirely abnormal is shown by Diagram M. wherein the consumption of spring waters per 100,000 population in Lawrence is graphically compared with that in a number of other cities. The diagram will show at a glance that the use of spring water per capita in Lawrence is many times that in any of the other five representative cities. There must be some reason for this striking contrast, and we believe the reason to lie more or less self-evidently in the dissatisfaction of the public with the municipal water supply.

It must be a genuine complaint that will cause consumers to pay about 300 times as much per gallon for the spring water as they would have paid for drinking water which might be drawn from any municipal tap. —and this is the ratio of costs in Lawrence.

Those who object to drinking Merrimac River water find a ready, though somewhat expensive recourse, in the bottled spring waters, and the extent to which such waters replace the municipal supply (1523) for drinking

purposes is a direct measure of the number of objectors to the latter, and hence of the unpopularity of that supply. The conception is by no means a novel one; the same condition has been found to govern in other communities where there are those who take exception to the quality of the public water supply.

The cost of the unpopularity of Merrimac water in Lawrence may therefore be estimated by the expense of spring water which is used as an alternative by the objectors, or by the expense of that amount of bottled water which is in *excess* of the normal. Normally, the sale of bottled spring waters in any of our large cities is limited almost entirely to office buildings where the principal consideration is the convenience of the container itself, this being readily handled and iced.

(1524) "What profits it to develop a public water supply at large cost, so that it is free from infection and so that it is even of good appearance, if the public —or a considerable part of it,—refuse to drink that water? Whatever reasons the public may have for this attitude are irrelevant to the conclusion so long as those reasons cannot be overcome.

Moreover, after all it is the people who are paying for their water supply, and surely from a business standpoint there can be no good reason against giving them the thing they want, if they can afford its cost.

Accordingly, we must consider further use of the Merrimac River for a source of supply as a thing to be avoided if at all practicable, or at all compatible with the interest of economy."
(1526)

"In chapters V and VI we have seen that only a minor improvement in the raw river water may be gained by taking it at a point immediately above Lowell, rather than at Lawrence, and, in general, that slight, if any, improvement in the final effluent from the works of Project 3 may be expected in comparison with Project 1. These remarks apply with equal force to the Concord River project, and accordingly we conclude that both should be rejected:

"*Disadvantages*: No matter how well safeguarded, the project would be subject (at least to some extent) to the menace as well as to the sentimental stigma, of a heavily and dangerously polluted source of water supply,—that would not only be ever present but would continually increase with the increasing pollution attending the growth of population on the watershed. On account of the high organic content of the raw water, odors and tastes characterized as "very faint", would give rise to occasional complaints, both real and imaginary, affecting the value of the water supply to its detriment."

(1527) "Although color of the purified and treated waters would conform to our standard of not over three parts per million, it would nevertheless be sufficiently high to cause occasional complaint. We would expect that the most serious disadvantage would arise simply from the "sentimental" objection to using water from a highly polluted source, and one which would hold in the the minds of laymen, regardless of the effectiveness of the purification process."

Page 21. "We find that the loss to the community which is directly chargeable to sentiment against using water from the Merrimac River, would amount to about $16.00 *per million gallons of water supplied to the city.*"

In addition to the above excerpts, the complainant introduced other excerpts from that report; these excerpts are contained in Ex. C-40 which is herein set forth:

In commenting upon the excerpts contained in that exhibit, Mr. Jacobs said,

"The only thing which these excerpts show is that one of the advantages of the site finally recommended was that the Merrimac River could be pumped and stored in this recommended reservoir on Bartlett's Brook, storage of Merrimac River water for purification is also indicated in the consideration of the Fish Brook project. But as stated under that project the storage of Merrimac River water is not finally rec-

ommended, and one of the reasons for it was that the drainage area of the storage reservoir which we finally located on Bartlett's Brook had sufficient drainage area so that it was not necessary to start pumping, although it was taken into consideration. Some of the other excerpts merely show the prejudices and the inefficiency which existed in Lawrence, all of which I feel has been corrected by the project as outlined for a much larger District than the small city of Lawrence. I believe it has been testified by Mr. Dooley that in spite of the fact that this report was made 13 years ago and other reports have been made since, Lawrence still takes its water out of the Merrimac, and the filtration plant has been improved."

Chapter I— Pages 14 and 15

"* * * * In the same year Mr. D. J. O'Mahoney, manager of the filter, demonstrated that if not hampered by political interference, about one-third of the total cost of filter operation and maintenance could be saved each year,—an interesting commentary on working conditions and by no means an unimportant matter. Unfortunately, the demonstration has not borne much fruit.

Continued Dissatisfaction:—On account of increasing difficulties in filtering enough water to supply the city, particularly during the winter months, the pleas of the filter management for additional capacity became yearly more insistent. Their recommendations were for covering and rebuilding the old filter. * * * *"

Chapter II—Page 33

"* * * * Years ago it was demonstrated by a careful study and many experiments that one of the Lawrence filter beds could be scraped most economically by a gang of about ten men. Such a gang of men represents the usual maintenance force always at the plant. All too often however, the scraping gang has had to be increased to double and sometimes treble the most economical force, on account of the desire for work—lack of work for city laborers elsewhere, and sometimes,—unfortunate to relate,—to a desire to find places for

men to work. The result of course has been uneconomical filter scraping and expensive operation costs, because much time and energy is lost through the men getting in each other's way. * * * *"

Chapter II—Pages 41 and 42

"* * * * We have attempted, in the foregoing to discover some of the causes for the excessive cost of filtration at Lawrence. To recapitulate them they are briefly:

(1) Lack of modern type of construction and proper equipment.

(2) Clogged filtering material, which adds greatly to the troubles, increases the cost and reduces the output of the filtration process.

(3) Certain incorrect and doubtless inefficient methods of operation, which are now and always have been in existence at the Lawrence filters.

(4) The hampering and expensive influence of an over-manned force.

All of these difficulties may be remedied and we are at liberty to conclude therefore, with properly constructed and equipped filters, the introduction of improved methods in operation and by divorcing filter operation from politics, that costs of filtration not more than half as great as those which now prevail are readily possible at Lawrence. * * * *"

Chapter VI—Pages 8, 9 and 12—Referring to the Fish Brook project, Mr. Knowles said:—

"* * * * *Description of Proposed Works:*—This, essentially, is a purification project in which the preliminary treatment is accomplished by storage and dilution.

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Since this supply is insufficient for Lawrence even at the present time, the deficiency is to be made up by pumping water from the Merrimac River to the reservoir, where a dry weather storage of about 160 days would be obtained. We could confidently expect that this would effect a considerable improvement in the character of the raw Merrimac River water, both because

of dilution and because of the effect of storage. Color would be reduced to about 40 percent of that in the raw river water, while practically all turbidity and most of the suspended matter should be removed. We may expect a bacterial reduction of not less than 85 per cent, if figures are based upon bacterial counts of the raw river water.

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Alternative Site: Fish Brook offers one of the two available sites for accomplishing the preliminary treatment of the Merrimac River water by storage. The other site is at Bartlett Brook on the opposite side of the river, and lying about two miles due north of the proposed Fish Brook Reservoir. This project will be considered later, in Chapter 7, as an independent source of water supply; since the available watershed at this site is large enough so that recourse to the Merrimac River for an auxiliary supply is not necessary, within the period of our comparative design. * * * *"

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Chapter XI—Page 9

Referring to the Bartlett's Brook project as finally recommended for Lawrence, Mr. Knowles said:—"It may be worth while to point out that one of the advantages of this project,—albeit a doubtful one from the standpoint of quality,—is that in case of emergency, Merrimac River water could be pumped into the reservoir, to be stored for a long time, to supplement the supply. * * * *"

QUALIFICATIONS OF EXPERTS

NATHAN B. JACOBS, an expert witness for Connecticut, (218) is a Civil Engineer residing in Pittsburgh, Pennsylvania. He is Vice-President and executive in charge of the organization of Morris Knowles Incorporated. He was graduated from the University of Pittsburgh in 1914, receiving the degree of Bachelor of Science from the Department of Sanitary and Hydraulic Engineering. In 1917, he received the degree of Sanitary Engineer from the University of Pittsburgh. Shortly after graduation in 1914, he became associated with Mr. Morris Knowles, and his professional work since that date has been in association with Mr. Knowles. Prior to that, he had experience in municipal engineering and sanitation, including work in connection with the construction of the filtration plant in Pittsburgh. In 1920, (219) he was associated with Mr. Knowles and Mr. Frank W. Main of Pittsburgh in the formation of the Knowles-Main Appraisal Bureau. He was associated with Mr. Knowles in 1918 in the organization and operation of Morris Knowles Limited, a Canadian corporation organized for handling work in the Dominion of Canada.

From 1914 to 1917, he was engaged in water supply and sewerage engineering, in investigations involving sanitation and in studies on the occurrence of typhoid fever. He did investigation, design and supervision of construction work on water supplies and sewerage works in many municipalities in Pennsylvania and Eastern United States. During that time, his work included valuations, appraisals and financing of publicly and privately owned utility properties. In 1917, when Mr. Knowles went to Camp Meade as Supervising Engineer representing Morris Knowles Incorporated, and Mr. Maurice R. Scharff, Mr. Knowles' principal assistant, went to Camp McClellan, Mr. Jacobs had charge of the general office of Morris Knowles Incorporated in Pittsburgh and had much of the responsibility, under Mr. Knowles' direction, of the work of the office, involving water supplies, sewerage and utility improvements of many municipalities and public service companies.

Since 1921, (220) he has been principal assistant to Mr. Knowles and has had responsible charge of Mr. Knowles' organization. The work of the organization has included water supply, sewerage investigations, city planning studies, hydraulic studies, considerable appraisal and valuation work, and the operation of a laboratory which was started in 1917 and which does a great deal of bacteriological and chemical analysis of water. Among the larger municipalities, he has served private corporations in Williamsport, York, Sunbury and Pittsburgh, Pennsylvania. He has acted for the last five or six years as manager of the Lewistown-Reedsville Water Company, a privately owned corporation supplying a small metropolitan district comprising several boroughs and towns in Central Pennsylvania. He has been in charge of a sanitary investigation of the Alleghany River, one of the principal tributaries of the Ohio River, dealing principally with the industrial waste conditions in the river. He had charge of much of the investigation for the mine pollution case often referred to as the "Indian Creek Case," involving pollution by mine wastes of the water supply of the Pennsylvania Railroad. During the period that the Engineering Board of Review of the Sanitary District of Chicago was in session, he was principal assistant for the committee on the construction program. Mr. Knowles (221), was Chairman and there were associated with him on the Committee some of the most eminent engineers in the country. His work was preparing sketches and studies for the development and construction of the sewage purification and intercepting system involving expenditures estimated at that time at about $125,000,000. He has made hydraulic studies for the Pittsburgh Flood Commission on the effect of storage dams on flood conditions in the Ohio River basin. In valuation and appraisal work, he has been associated with a number of the larger projects involving water utilities, such as the supply of the cities of Scranton and Wilkes-Barre, and with numerous others involving not only the valuation of the structures, but in many cases, the valuation of water power rights and water power developments. He made an appraisal of the entire works

and property of the Alabama Power Company, a $38,000,000 corporation, owning numerous dams and water power rights both developed and undeveloped, throughout Central and Northern Alabama and Tennessee. He has always considered himself, (222) as working under Mr. Knowles' direction, with the exception of a few months when Mr. Knowles was very seriously ill. By the end of the war, the Pittsburgh office of Morris Knoles Incorporated employed about two hundred men. During the war, he conducted some of the investigations on water supply for the Housing Division of the United States Shipping Board.

MAJOR EZRA B. WHITMAN, an expert witness for Connecticut, (334) is a Consulting Engineer residing in Baltimore, Maryland. He was educated in the private and public schools in Baltimore, attended the Baltimore City College, and was graduated at Cornell University with the degree of Civil Engineer in 1901. In 1904, he took a special course in chemistry and bacteriology in the Cornell Medical School. After graduation from Cornell, in 1901 and 1902 he was employed by the Bacterial Sewage Purification Company of New York, and while with that company had charge of the design and construction of about twelve small sewage disposal plants for large country estates and institutions. In 1902, he went to Chicago with the Cameron Septic Tank Company of that city and had charge of the design and construction of three institutional plants for the State of Iowa and one for the State of Missouri. In 1902, he became a member of the firm of Williams and Whitman, Sanitary Engineers, in New York City. As a member of that firm, (335) he designed sewerage systems for Havre de Grace, Maryland; Tacoma Park, Maryland; Sayre, Pennsylvania; Spring Grove, Pennsylvania; Leetonia, Ohio; Revena, Ohio and Newton, New Jersey. He designed sewage disposal plants for Tacoma Park, Maryland; Waverly, New York; Ithaca, New York; Leetonia, Ohio; Ravena, Ohio; Marion, Massachusetts, and Newton, New Jersey, the National Home for Disabled

Volunteer Soldiers at Johnston City, Tennessee, and the State Hospital for Tuberculosis at Raybrook, New York.

In 1906, he was appointed Division Engineer of the Baltimore Sewerage Commission, which had charge of the design and construction of practically a complete storm water and sanitary sewer system for the City of Baltimore. His position was that of Division Engineer in charge of sewage disposal. In this position he took charge of the Sewage Testing Station, carried on experiments with regard to various features of construction, and as a result of that experimental work, determined certain features of design for the Baltimore sewage disposal plant. He had complete charge of the design and construction of the main sewage disposal works for that City, and also of sewage disposal plants in several of the outlying districts which could not be brought into the main sewer system.

From 1914 to 1916, (336) he was a member of the firm of Greiner and Whitman, Consulting Engineers of Baltimore, from 1916 to 1925, a member of the firm of Norton, Bird and Whitman, and from 1925 to date, a member of the firm of Whitman, Requardt and Smith. He has designed sewer systems for Towson, Arlington and Govans, Maryland, which are suburban sections just outside of Baltimore, for Little Falls Brook drainage area adjoining Washington, (337) for Rockville, Maryland; Christield, Maryland; Macon, Georgia; Winchester, Virginia; Aberdeen, Maryland; Dundalk, Maryland; Wawasett Park, Delaware; for the DuPont Company at Conagona in the Province of Quebec, Canada; for Overlea, Maryland; and Fort Thomas, Kentucky. He had charge of the actual construction of sewers in a number of these places and of the sewage disposal plants in Macon, Aberdeen and Dundalk. He made a valuation of sewerage systems and sewage disposal plants for the Mount Washington Sewerage Company, for the Development Aid Corporation and for Elizabeth City, North Carolina. He designed sewage disposal plants for Newark, Delaware and Fort Thomas, Kentucky, and Dundalk,

Maryland. In 1911, after leaving the Sewerage Commission in Baltimore, he was appointed Chief Engineer and President of the Water Board of Baltimore City. He had complete charge of the maintenance and operation of the entire water plant for the City of Baltimore while occupying that position, and also had complete charge of the design and construction of a number of improvements to the existing system, including the building of a new dam. He designed, (339) a pumping station of 160 million gallons per day capacity, a filtration plant of 126 million gallons per day capacity, and several other pumping station improvements. He resigned as Chief Engineer of the Water Department in 1914, but he was retained by the City of Baltimore as Consulting Engineer to take charge of the improvements started under his term as Water Engineer for the city. He has made reports on the water supply for Bristol, Virginia, and designed and constructed water systems for Dundalk, Maryland and Wawasset Park, Delaware. He made a report on a new water supply and designed and had charge of construction of water supply improvements for Winchester, Virginia; Ellicott City, Maryland; Sudbrook Park, Maryland; Martinsburg, West Virginia; Conacona, Province of Quebec; and Frostburg, Maryland. He was Consulting Engineer to the City of Covington, Kentucky, on the subject of water supply improvements following a typhoid epidemic. He is (341) engineer for the City of Albany on the new water supply for that city. He was on the Public Service Commission of the State of Maryland for 6½ years and occupied the position of Chairman of that Commission during 1924. For the past eight years he has been a Trustee of Cornell University. He is at present engaged in a valuation case before the Public Service Commission in Maryland of fifteen electric properties in the State. During the war, (342) he was in the Construction Division of the Army, which had charge of all the construction that was done in this country. He was commissioned Major. While he was a member of the Public Service Commission in Maryland, (363) there was tried before the Commission the Conowingo Case, involving the question of the

economic feasibility of the Conowingo Power Project. He has made (364) valuations of water power at the Union Bridge Milling Company and of three water powers on the Gunpowder River. He built a hydro-electric plant in connection with the Baltimore sewage disposal work—a plant of about 225 horse power. He made a study (367) for the Union Gas and Electric Company of Cincinnati and the Columbia Power Company to determine the price to be paid for power generated at the Columbia Power Company's 100,000 K. W. station on the Ohio River, supplying Cincinnati and vicinity. The Consolidated Gas, Electric Light and Power Company (368) employed him to review its contract with the Pennsylvania Water and Power Company for purchase of hydro-electric current. He was a member of the Engineering Board of Review of the Sanitary District of Chicago and served on two committees, one of which (369) was the Committee on Water Supply and the other the Committee on Water Power. While engaged in that work, he examined all of the water power plants in the neighborhood of Niagara, both on the Canadian and American sides. As a member of the Committee, he made a comparison of the relative value of water power in the valley of Niagara and in the valley of the St. Lawrence, as compared to water power along the Illinois River. He has made a study of the possibilities of power development along the Canadaigua outlet of Lake Cayuga. He has made a study of the possibilities and cost of developing power (370) from Lamoka Lake to Kenka Lake. He has had a number of occasions to investigate the cost of operating hydro-electric plants.

DR. WILLEM RUDOLFS, an expert witness for Connecticut (414) is Professor of Water Supply and Sewage Disposal at Rutgers University, New Jersey, and lives in Dayton, New Jersey. He is also Chief of the Department of Water Supply and Sewage Disposal of the New Jersey Agricultural Experiment Station and is in charge of the water and sewage

plants for all State institutions in New Jersey. He does consulting work, having been employed as consultant by the Port Raritan District Commission of New Jersey to investigate the stream conditions of the Raritan River. He was born in Holland and attended the University there for about six years. He was trained as a chemist, botanist and bacteriologist. He came to the United States (415) in 1916 and went to the University of Illinois for about 2½ years where he was employed as a chemist and did part-time study. From there, he went to Rutgers University and was appointed Research Fellow, making studies in chemistry and bacteriology. Following this he was appointed Research Fellow by the Pasteur Institute at Paris, France. On his return to the United States, he was appointed Chemist Research Fellow at Rutgers University for one year and was then appointed biochemist. Following that (416) he was appointed to his present position as Chief of the Department of Water Supply and Sewage Disposal, and later, to be Professor. The Department of Water Supply and Sewage Disposal is a research agency, working under a State statute for investigation of the biology of sewage disposal and makes many reports and publications on results of its work. More than seventy publications and technical articles have been written, besides some fifty others which do not deal directly with water treatment and sewage disposal. He is retained by the State of New Jersey in the suit between New Jersey and the State of New York before the United States Supreme Court and has been in charge of the investigations dealing with stream pollution in connection with that case. He has been retained by the International Coal Combustion Company in a stream pollution case before the Chancery Court in New Jersey. For a number of years, he has been consultant for the City of Milwaukee on their sewage disposal problems. A year ago he was appointed by the Public Health Section of the League of Nations to make an investigation in Germany, Holland and England of stream pollution, (417) and water and sewage conditions, for the purposes of an extensive report.

PROFESSOR C.-E. A. WINSLOW, an expert witness for Connecticut, (501) is Professor of Public Health at Yale School of Medicine, and resides at 314 Prospect Street, New Haven, Connecticut. He graduated with the degree of Bachelor of Science from the Massachusetts Institute of Technology in 1898, and took his Master's degree in 1899. Since that time, he has been continuously engaged in teaching and research in the field of public health at the Institute of Technology, the University of Chicago, the College of the City of New York, and since 1915, at Yale University. He has served also (502) at various times as a member of the staff of the Massachusetts State Board of Health and the New York State Department of Health. For the past 12 years, he has been a member of the Public Health Council of the State of Connecticut. Since 1918, he has been a member of the Health Committee of the League of Nations at Geneva and a member of the Board of Scientific Directors of the International Health Division of the Rockefeller Foundation. From 1903 to 1910, he was in charge of the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology, which was then conducting extensive investigations on sewage treatment. Later, he was the Chairman of the special committee in charge of the preliminary experiments on the treatment of sewage at New Haven. He is joint author, with the late Professor Kinnicutt of Worcester and Mr. R. W. Pratt, of the textbook "Sewage Disposal," and in collaboration with Professor S. C. Prescott of the textbook "Elements of Water Bacteriology," as well as of various other books on public health and of articles in the technical press. He was connected, as an expert advisor, with the investigations leading to the construction of the Charles River Dam. He testified in the Jersey City Water Case in 1907 and 1911, the Chicago Water Pollution Case in 1910, the Auburn Water Case in 1912, 1913 and 1914, and as an expert (503) for the United States Bureau of Chemistry in various water and food cases. As a member of the Industrial Wastes Board of Connecticut, he was responsible for various studies of stream pollution.

JOHN H. GREGORY, an expert witness for Connecticut. Residence: Baltimore, Maryland.

Business: Consulting Engineer. Also Professor of Civil and Sanitary Engineering in the John Hopkins University—head of the Civil Engineering Department in the School of Engineering, and head of the Sanitary Engineering Department in the School of Hygiene and Public Health.

Education: Graduate of Massachusetts Institute of Technology, Boston, Massachusetts—Class of 1895—in Civil Engineering.

For the last thirty-four years, actively engaged in the design and construction of water supply and water purification works, including dams, reservoirs, pipe lines, slow sand filtration plants, rapid sand filtration plants, and pumping stations. Also similar work in sewerage and sewage disposal, such as sewers, storm water drains, sewage pumping stations and sewage disposal works. Also valuation, mainly of water works properties.

In the summer of 1893, Office Assistant in the Metropoliton Sewerage Works at Boston and on surveys and designs of sewerage works.

In the summer of 1894, again with the Metropolitan Sewerage Works of Boston as draftsman and transitman on the construction of the outfall sewer at Deer Island, Boston Harbor.

From 1895 to 1897 in Boston as an Office Assistant in the Metropolitan Water Works, engaged largely on studies and designs for the Wachusett Aqueduct and Wachusett Dam, two low dams and large distribution mains.

From 1897 to 1900 in Albany, N. Y. as Assistant Engineer and Resident Engineer on the water filtration plant, covering the design and construction of a 15 m.g.d. filtration plant, pumping station and steel pipe line.

From 1900 to 1902 in Philadelphia, Pa. as Assistant Engineer in charge of designs on the improvement, extension and filtration of the water supply. These designs covered the first four filtration plants built by the City of Philadelphia, having capacities respectively of 6½, 15, 33, and 100 m.g.d. At the time the Torresdale filter plant, having a capacity of 100 m.g.d., was put under construction, it was the largest single filter plant in the world. The designs also included an uncovered raw water reservoir and an uncovered filtered water reservoir, also four covered filtered water reservoirs. Designs further covered two pumping stations, one of which had a total capacity of 120 m.g.d. Also, contract drawings for large distribution mains in the City proper.

From 1900 to 1902—Division Engineer on the Jersey City Water Supply Company, Jersey City, N. J. This was a water supply works having a capacity of 50 m.g.d., a masonry dam, a storage reservoir, and a water conduit 26 miles long. Was in charge of the construction of the conduit, numerous detail drawings for the dam and conduit, and also a small amount of engineering work at the filtration plant and pumping station of the East Jersey Water Company at Little Falls, N. J.

From 1903 to 1904—In New York City as Principal Assistant Engineer in the Filtration Department of the Commission on Additional Water Supply, which was engaged in studying the additional sources of supply for New York City. The work covered investigations, studies, designs and estimates of cost of a proposed 500 m.g.d. water filtration plant and also investigations and studies of works for filtering the existing Croton water supply in New York City.

From 1904 to 1909 in Columbus, Ohio, as Engineer in charge of design and construction of water and sewerage works. The water works consisted of masonry dam 30 feet high, 1,000 feet long; a storage reservoir having a capacity of 2,000,000,000 gallons, six miles long; a rapid sand water filtration plant having a capacity of 30 m.g.d.; and a new pumping station having

a capacity of 40 m.g.d., together with large distribution pipe lines. The sewerage works consisted of a sewage disposal works 20 m.g.d. capacity, two sewage pumping stations, sewers and sewage force mains, and other miscellaneous work. Also the design of a sewage testing station, which was operated for a period of one year, to determine the best method of treating the sewage of the City.

From 1909 to 1910—Resident Engineer on the Passaic Valley sewerage project in the Passaic Valley, N. J., covering surveys and plans for the Passaic Valley sewer which was later built from Great Falls, Paterson to Newark Bay, and collecting the sewage from twenty cities and towns in the Passaic Valley, the largest cities being Newark, N. J. and Paterson, N. J.

From 1910 to 1911 in New York City as Engineer with the Metropolitan Sewerage Commission, engaged on investigations and studies of sewers and works for collecting and disposing of the sewage of New York City.

From 1901 to 1911 also engaged on miscellaneous water filtration work in connection with filtration works built at Milford and Springfield, Mass.; Jamaica, Long Island, N. Y.; Youngstown, Ohio; New Haven, Conn.; New Milford, N. J.; and Montreal, Quebec, Canada.

From 1911 to 1917 in New York City as a member of the firm of Rudolph Hering and John H. Gregory, Consulting Engineers, largely in connection with water supply and sewerage works.

From 1917 to 1919 in New York City in private practice, as consulting engineer on similar work.

From 1919 to date in Baltimore, Maryland in private practice as consulting engineer and also connected with the Johns Hopkins University.

From 1911 to date, connected with many water supply and water purification, sewerage and sewage disposal works and valuation, some of the more important of which are as follows:

Albany, N. Y.—Sewage disposal investigation and report and contract plans and specifications for sewage disposal works, which has a capacity of 30 m.g.d. Also sewage pumping station which has a capacity of 60 m.g.d.

Atlanta, Ga.—Consulting Engineer on sewage disposal works during construction.

Austin, Tex.—Sewage disposal investigation and report, plans for sewage disposal works and sewage pumping station, and served as Consulting Engineer during construction.

Baltimore, Md.—Investigation and report on the adequacy of design and construction of a filtered water reservoir then under construction; investigation and report on deferring construction of a new pumping station; and investigation and report on character of construction of additions to the existing rapid sand filtration plant.

In 1928, made a report to Baltimore on the next future water supply, recommending a new source of supply, with filtration, and locating it entirely independent of the existing source of supply. Also valuations of seven private water companies which were acquired by the City. Capacity of new source of supply recommended—80 m.g.d.

For the Sanitary District of Chicago—Was a member of the Engineering Board of Review having to do with the Lake Level Controversy and the disposal of the sewage of the Sanitary District. Was a member of the Sewage Disposal Committee and later appeared as a witness in the re-reference before Mr. Hughes, on questions relative to sewage disposal.

Charleston, S. C.—Investigation and report on water sup-

ply and made the valuation for the City of Charleston Light and Water Company, which property was later acquired.

In 1919 made a report to the City of Columbus, Ohio on additional water supply works and for five years served as Consulting Engineer on the construction of these works, which consisted of a dam 64 feet high and 1,750 feet long; a storage reservoir, capacity 5,300,000,000 gallons, 8 miles long; enlargement of the filtration plant from 30 to 54 m.g.d., together with large water distribution mains.

In 1925 was one of a Committee of three engineers retained by the City of Detroit, Mich. to investigate and report on sewage disposal. The approximate estimated cost of works recommended was $39,000,000, and since that date a part of the work has been built.

Fort Worth, Tex.—Plans and specifications for enlargement of the existing water filtration plant and Consulting Engineer during construction. Also recommended the Lake Worth conduit, mainly a 60-inch reinforced concrete pipe some 5½ miles long; recently built.

During the construction of the Montreal, Quebec water filtration plant, capacity 60 m.g.d., served as Consulting Engineer representing Mr. Hering.

For New York City, N. Y., was one of a Commission of five engineers reporting to the Board of Estimate and Apportionment on filtration of the Croton water supply.

For Trenton, N. J., several investigations and reports on sewage disposal and preparation of detail plans and specifications for sewage disposal works and sewage pumping station.

For the last eight years, and at present, Consulting Engineer to the Sewer Department of Baltimore, Md., relative to the construction of the larger new main sewers, as well as on the

enlargement of the existing sewage disposal works. Also Consulting Engineer to the Public Improvement Commission of Baltimore on new water works improvements estimated to cost about $10,000,000 some of which work is now under construction, and other work being designed; and included in the same is a new storage reservoir having a capacity of about 23,000,000,000 gallons and a masonry dam about 133 feet high.

For the last three years, and at present Consulting Engineer for the City of Columbus, Ohio on sewers and sewage disposal works, the approximate cost of which will be upwards of $10,000,000, and a part of which is now under construction.

Has twice served the Maryland Public Service Commission of Maryland in connection with valuation of water works properties, and was engineering advisor to the City Solicitor of Baltimore and made the valuations of six water companies and one sewerage company, all of which properties have been acquired by the City of Baltimore. Also valuations of other water works properties elsewhere.

Member of the American Society of Civil Engineers, American Society for Municipal Improvements, American Society for Testing Materials, American Public Health Association, American Water Works Association, Boston Society of Civil Engineers, New England Water Works Association, and others.

Has written numerous papers and articles and discussions on water supply and water purification, sewerage and sewage disposal, hydraulics, etc., and have reviewed numerous books, for the engineering press, relative to the above subjects.

Has twice visited Europe and inspected the leading water supply and sewerage works in Belgium, England, France, Germany, Scotland and Switzerland.

DR. MONT FRANCIS MORGAN, an expert witness for Connecticut, Technical Training and Experience: B.S. (in Agr.) West Virginia University, 1920. One-half year graduate work there. Instructor in Soils, West Virginia University, 1920-1921. Master of Science degree, Ohio State University, 1922. Assistant Professor of Soils, Ohio State University, 1922-1923. Present position, Chief of Department of Soils, Connecticut Agricultural Experiment Station, since July, 1923. Also Associate Professor of Soils, Yale School of Forestry, Yale University, since 1928.

Technical publications:

(1) Factors Affecting Soil Reaction. I. The Soil Water Ratio. Jour. of Phys. Chem. 27: 117-140. 1923.

(2) Solubilities of Limestone as Related to Their Physical Properties. Soil Science 15: 293-305.

(3) Liming Materials. Timely Soil Topics, Ohio State University. 1923.

(4) Land Cover Studies as a Basis for a More Accurate Interpretation of the Soil Survey. Jour. of Am. Soc. of Agron. 16: 452-458.

(5) Practical Lawn Suggestions. Bul. of Immediate Information No. 48, Connecticut Agricultural Experiment Station.

(6) The Phosphorus Requirements of Old Tobacco Soils. Tobacco Station Bul. No. 7, Connecticut Agricultural Experiment Station.

(7) Should the New England Farmer Maintain Two Cropping Systems, One with Lime, the Other Without? Jour. Am. Soc. of Agron. 19: 683-684.

(8) Soil Acidity in Connecticut. Extension Bul. 101, Connecticut Agricultural College.

(9) Cropping Systems and Soil Efficiency. Extension Bul. 1 103, Connecticut Agricultural College.

(10) A New Field Method for pH Determinations. Ecology 8: 387-388.

(11) Soil acidity Methods as Applied to Soil Survey Work. Jour. Am. Soc. of Agron. 20: 881-892.

(12) Tobacco as an Indicator Plant in Studying Nutritional Deficiencies of Soils under Greenhouse Conditions. Jour. Am. Soc. of Agron. 21: 130-136.

(13) Soil Reaction and Liming as Factors in Tobacco Production in Connecticut. Bul. 306. Connecticut Agricultural Experiment Station.

(14) The Effect of Some Nitrogenous Fertilizers on Soil Reactions. Tobacco Station Bul. No. 10, p. 51-55, Connecticut Agricultural Experiment Station.

(15) Organic Matter in Tobacco Soils, Tobacco Station Bul. No. 10, p. 66-72. Connecticut Agricultural Experiment Station.

(16) A Study of Factors Affecting the Estimation of Lime Requirement from pH Values. Accepted for publication, but not yet published. Soil Science. 1930.

(17) A Spot-Plate Method for the Estimation of Nitrate Nitrogen in Soil and Other Extracts. Accepted for publication, but not yet published. Science. 1930.

DR. FRANK E. WINSOR, an expert witness for Massachusetts, Graduate of Scientific course, Brown University with degree of Bachelor of Philosophy, 1891; received degree of Civil Engineer 1892; Master of Arts 1896, and honorary degree of Doctor of Science in 1929. Was engaged on the construction of the Metropolitan Sewerage System, Boston, Mass., from 1891 to January, 1895; from January, 1895, to October, 1895, engaged on design of various sewer systems and was also Resident Engineer on construction of sewerage system for Natick, Mass., including pumping station, intermittent sand filters, etc.; October, 1895 to January, 1903, was engaged on the design and construction of the Metropolitan Water Works, including five years on the Wachusett Reservoir work and about two years on the construction of the Weston Aqueduct as Division Engineer. During the greater part of 1903 was engaged as Division Engineer upon investigations for an additional water supply for the City of New York; from November, 1903 to April, 1906 was engaged first as Designing Engineer upon investigations for an additional water supply for the City of New York; from November, 1903 to April, 1906, was engaged first as Designing Engineer and later as Principal Assistant Engineer on the design and construction of the Charles River Basin, Boston, Mass. From April, 1906 to August, 1915, was engaged on the Catskill Water Works system for New York City, being the first four years Senior Division Engineer of the Southern Aqueduct Department, and later Department Engineer in charge of the construction of the Hillview Reservoir, Kensico Reservoir and Dam, and about 32 miles of the Catskill Aqueduct, construction cost alone aggregating some $25,000,000. The 32 miles of aqueduct included some 13 miles of tunnel, 16 miles of large masonry aqueduct and 3 miles of steel pipe. From August, 1915, to September, 1926, Chief Engineer on the design and construction of a new water supply for Providence, Rhode Island, aggregating about $21,000,000, which supply included the Scituate Dam and Reservoir, the filtration plant of 50,000,000 gallons capacity, aqueduct, with tunnel three and a half miles long connecting pipe lines into

the distribution system, covered reservoirs, etc., From September, 1926, to date, Chief Engineer for the Metropolitan District Water Supply Commission, and until the summer of 1928 when the work on the new system of Providence was completed, acted also as Consulting Engineer upon that system.

Past president Providence Engineering Society, past president New England Water Works Association, president Boston Society of Civil Engineers, vice president American Society of Civil Engineers, member and past director Municipal Engineers of the City of New York, member American Water Works Association, Brown Engineering Association, etc.

ROBERT SPURR WESTON, an expert witness for Massachusetts.

Born—Concord, N. H., August 1, 1869.

Graduated Amherst College, 1891, B. S. A. M. 1894.

Assistant in industrial laboratories, 1891-1894.

Graduate student, Massachusetts Institute of Technology, 1894-1895.

First assistant chemist, Louisville Water Purification Experiments, 1895-1896.

Graduate student at the University of Berlin, Germany, 1897-1898.

Assistant on Water Purification Experiments for Louisville Water Co., Kentucky, Part of 1898.

Assistant to George W. Fuller, Professor Erastus G. Smith and others in connection with various water purification and

stream pollution studies, including those for the water works at York, Pennsylvania; Hornell, New York; and West Superior, Wisconsin. Also re-built water purification plant at Henderson, N. C. 1898-1899.

In addition to the above, served for short periods as Assistant for the Massachusetts State Board of Health, and a volunteer assistant in the laboratories of the Massachusetts State Board of Health (summer of 1894), and the Imperial Board of Health of Germany, (winter of 1898).

For 30 years, or since 1899, in private practice at 14 Beacon Street, Boston, Massachusetts; since 1916 under the firm name of Weston & Sampson, whose practice lies in the field of water supply, water purification, sewerage and sewage treatment, or what is sometimes called Public Health Engineering.

Among the important works are the following:

Water Purification Investigations at

Washington, D. C.
New Orleans, La.
Ansonia, Conn.
United Fruit Company, Cuba.
Salem-Beverly, Mass.
Biddeford and Saco Water Company, Maine.
Brookline, Mass.
Chester, Penna.
Cohasset, Mass.
E. Providence Water Company, R. I.
Exeter, N. H.
Hagerstown Water Company, Md.
Hartford Water Company, Vt.
Keene, N. H.
Knoxville Water Company, Tenn.
Oxford Paper Company, Maine.
Newport Water Works, R. I.

Pittsburgh, Pa.
Reading, Mass.
So. Orange, N. J.
(and other places).

Construction of Water Purification Plants

Amesbury, Mass.
United Fruit Company, Cuba.
Belfast, Maine.
Cohasset Water Company, Mass.
Exeter Water Works, N. H.
Gorton Pew Fisheries, Gloucester, Mass.
Hartford, Conn.
Hartford Water Company, Vt.
Keene, N. H.
Merrimack, N. H.
Middleboro, Mass.
Mt. Holyoke College, Mass.
Newmarket, N. H.
Oklahoma City, Okla.
Old Town, Maine.
Reading, Mass.
Sayles Finishing Plants, R. I.
Sayles-Biltmore Bleacheries, Asheville, N. C.
So. Orange, N. J.
Wakefield, Mass.
(and other places).

Reports on Water Supply—Studies of Stream Pollution

Study of Ten Mile River, Mass.-R. I.
Bayonne, N. J.
Berlin Water Company, N. H.
Billerica, Mass.
Charles River Basin
Dover, N. H.
Blackstone River, R. I.

Seekonk River, R. I.
Neponset River, Mass.
Squannacook River, Mass.
Assabet River, Mass.
Leamington, Ont.
Lebanon Water Company, N. H.
Litchfield Water Company, Conn.
Lynn, Mass.
Sudbury River (for Met. Dist. W. S. Comm.)
Oxford Paper Company, Maine.
Sanitary survey of water sources for Newark, N. J.
Newton, Mass.
North Jersey District Water Supply Commission

Consulting sanitary engineer from 1922 to date. Work includes special reports, supervision of sanitary engineering department and studies of waters in Northern New Jersey.

Nashua, N. H.

Shawsheen River, Andover, Mass.

This list does not include practice in the field of sewage treatment and in the treatment of industrial wastes. Much work has been done in this field particularly in Massachusetts and Rhode Island.

Neither does this list include a large amount of work done for various factories, clubs, hotels, parks, schools, office buildings, and private estates. Now over 13,000 analyses have been made in the laboratory at Boston. While most of the work listed has had to do with plants of less than 100,000 gals. daily capacity, the amount of work in the aggregate is large, and the experience gained thereby is important.

Neither does this list include over one hundred cases of treatment of sewage, nor other public health engineering work like the construction and supervision of swimming pools, the control of air-borne nuisances, or garbage and refuse disposal.

European Experience.

In addition to taking courses at the University of Berlin in 1897-1898, Mr. Weston made a special study of deferrization of iron removal plants in 1907-08 (see paper Journal Am. Soc. C. E. *64,* 112.) He also made studies of various European water supply and sewerage works at the same time.

Teaching Experience.

From 1912 to 1916, Mr. Weston was assistant professor of public health engineering (part time) at the Massachusetts Institute of Technology. During this period, the Sanitary Institute of the Massachusetts Institute of Technology made, under his direction, a study of the Coweeset River, an otherwise unpolluted stream which received the effluent of the Brockton sewage works.

Technical Papers.

Mr. Weston has written many technical papers which have appeared chiefly in the journals of the American Water Works Association, the New England Water Works Association, the American Society of Civil Engineers, the American Public Health Association and also in the "Engineering News-Record" and similar publications.

Book.

Mr. Weston is joint author of the "Water Works Handbook" (Flinn, Weston and Bogert), a standard treatise on the art of water supply.

Societies.

Mr. Weston is a member of the following professional and technical societies,—

Society	*Member since*
American Institute of Consulting Engineers, Director	1916
American Society of Civil Engineers, Past Chairman of San. Eng. Div.	1902
Boston Society of Civil Engineers—Past President	1903
Engineering Institute of Canada	1913
American Water Works Association	1898
New England Water Works Assoc., Pres.	1897
American Public Health Assoc., Fellow, and Chairman of Committee on Scope and Policy	1898
New England Sewage Works Association	1929
American Society for Municipal Improvements	1920
American Chemical Society, Past Chairman Northeastern Section	1894
American Institute of Chemical Engineers	1918
Society of Chemical Industry, Great Britain	1895
City Planning Conference	1920

Special Qualifications.

For the present case Mr. Weston's qualifications include his knowledge of the character of New England waters acquired by 30 years of practice and observation in this region.

He was engaged by the Metropolitan District Commission to make studies for presentation to the legislature when the matter of additional water supply was under consideration.

He has made many studies of the rivers of New England and elsewhere. Some of these studies have continued over periods of from ten to twenty years.

PROFESSOR EARLE B. PHELPS, an expert witness for Massachusetts.

Graduated Massachusetts Institute of Technology 1899 in the Department of Chemistry.

Assistant Bacteriologist, Massachusetts State Board of Health at the Lawrence Experiment Station engaged in investigation of water and sewage purification, 1899-1903.

Research Assistant, Assistant Professor, and Associate Professor, Massachusetts Institute of Technology 1903-1913. During this period associated with Professor Winslow at the Sanitary Research Laboratory dealing with investigations in sewage disposal, industrial waste disposal and stream pollution. Also during this period Assistant Hydrographer, U. S. Geological Survey engaged in field studies of stream pollution.

During the latter years consulting Sanitarian with offices in New York City. In this connection retained by the City of New York in conjunction with Colonel (now Brigadier-General retired) William S. Black to investigate pollution of New York Harbor and report upon a scheme of main drainage and sewage purification for the Metropolitan Area. Later engaged by the City in litigation before the United States Supreme Court, between the State of New York and New Jersey, relative to the pollution of New York Harbor.

Professor of Chemistry, Hygienic Laboratory, U. S. Public Health Service, 1913-19, in charge of investigations dealing with sewage disposal treatment, of industrial wastes, and of stream pollution. Assisted in planning the extensive investigations of the Ohio River which have been conducted continuously since that time and is, at present, member of Consulting Sanitary Engineer, International Joint Commission in charge of an investigation of the pollution of the boundary water between the United States and Canada and planning of remedial works required under the treaty.

In private consulting practice 1919-1924.

Professor Sanitary Science, College of Physicians and Surgeons, Columbia University, 1924 to date.

X. HENRY GOODNOUGH, an expert witness for Massachusetts.

Graduated from Harvard College 1882.

Engaged for a brief time in vacation on Boston main drainage work.

1883-1884 General railroad work in the west.

1885 Massachusetts Drainage Commission, making investigations and plans for the North Metropolitan sewerage system of Boston.

1885-1886 Boston main drainage system.

1886 Investigation and design of works for the improvement of Stony Brook in Boston.

1886-1895 Assistant Engineer, State Board of Health under Frederic P. Stearns, Chief Engineer.

1895-1914 Chief Engineer, State Board of Health.

1914-date Chief Engineer and Director, Division of Sanitary Engineering, Massachusetts Department of Public Health.

In connection with the work of the Board of Health:

1886 Assistant Engineer on investigations of Boston Water supply.

1887-1889 Re-investigation of the North Metropolitan Sewerage system.

1893-1895 Investigations for Metropolitan water supply.

1893-1894 Investigations for a design of Charles River dam and basin.

As chief engineer, beginning in

1895 Had charge of work of deepening and improving Concord and Sudbury rivers with rebuilding of necessary bridges.

1895-1897 Investigations for the improvement of the Neponset River and drainage of Fowl Meadows.

1895-1896 General charge of investigation for system of sewerage for Salem and Peabody.

1896-1898 Engineer, jointly with the late Frank W. Hodgsdon, of the town of Marshfield (Joint Board consisting of State Board of Health and Massachusetts Harbor and Land Commission).

1899-1900 In charge of further investigation of plans of the Metropolitan Sewerage Commission for a main sewer for the South Metropolitan District and a new outlet into the lower Boston Harbor.

1901 Investigation of the sanitary condition of the Sudbury and Concord rivers and the Meadows adjacent thereto.

1904 Investigation upon the disposal of municipal refuse in the city of Boston.

1906-1907 Improvement of Mystic River and Alewife Brook and design for a water supply for the city of Lynn.

1908 Investigation as to the best means of preventing the further pollution of Boston harbor by the discharge of sewage at Moon Island.

1909 Special studies upon the sanitary condition of various rivers.

1911-1915 Had charge of construction of works for deepening, straightening and enlarging the channel of the Neponset River, including the reconstruction of necessary bridges and water and sewer pipe crossings.

1913 Investigation of various rivers in Massachusetts.

1914 Preparation of design and plans for extension of the Metropolitan sewerage district in the Charles River valley.

1916 Jointly with engineer of the city of Lynn. Design of works for new sewerage system for that city.

1917-1920 Investigation upon the improvement of various rivers with plans therefor.

1919-1922 Engineer of the Joint Board, consisting of the Department of Health and the Metropolitan District Commission, in making investigations and preparing plans for the extension of the Metropolitan water supply system.

1923-1927 Various special investigations for a water supply for Lawrence, Methuen, Lowell, Salem, and other municipalities in Essex County and adjacent portions of Middlesex County.

1923-1925	Preparation of plans for a general sewerage system for Salem, Beverly, Danvers, Peabody, and certain Public institutions.
Since 1920	In charge of construction of works for water supply, sewerage, etc., for various public institutions.
Previous to 1920	Regulation of capitalization of rates and service of water companies.
1920 to date	Engineering adviser to the Department of Public Utilities on matters relating to water companies.
At present	Chairman of a board of engineers to investigate the pollution of Boston harbor and the necessity for an enlargement of the Boston main drainage and Metropolitan sewerage systems under a special commission made up of heads of departments of the State and the city of Boston.
1926 to date	Consulting engineer to the Metropolitan District Water Supply Commission.
1925 to date	Ex-officio member of the South Essex Sewerage Board appointed to carry out the plans designed by the Department of Health 1923-25.

Consulting engineer at different times

For the City of New York, sewerage.

City of Providence, R. I., water supply.
County of Los Angeles, sewerage.
Boston and Brookline, improvement of Back Bay Fens.
City of Boston, municipal waste disposal.

For many smaller places on various engineering matters.
Member of

American Society of Civil Engineers.
American Water Works Association.
New England Water Works Association (Honorary member).
Boston Society Civil Engineers.
Harvard Engineering Society (past president).
Society American Military Engineers.
American Meteorological Society.
American Geographic Society.

Member of various committees on engineering subjects.

Author of papers on various engineering subjects, including rainfall, stream flow, freshets, yield of watersheds, well water supplies, disposal of drainage, sewage and municipal refuse, etc.

Recipient of Dexter Brackett medal of the New England Water Works Association for 1921.

KARL R. KENNISON, an expert witness for Massachusetts (1832) designing engineer, Metropolitan District Water Supply Commission.

Graduated from the Massachusetts Institute of Technology in 1908.

With the exception of one year of teaching, has been practicing engineering since graduation.

Was for six years associated with John R. Freeman, consulting engineer, of Providence, R. I., rising to the position of principal assistant in charge of designs and estimates. This work included many projects for water supply and water power including reports on the development of the Mississippi River

at Keokuk, Iowa, and a report for the Hetch-Hetchy water supply for San Francisco.

During the war was supervising engineer of the Bureau of Yards and Docks of the Navy Department, and also with the Emergency Fleet Corporation in charge of shipyard construction in Mobile and New Orleans.

For six years following the war was engaged in private practice as consulting engineer in Boston on miscellaneous hydraulic problems, water supply, water power and flood control.

Since 1926 has occupied his present position.

JAMES F. SANBORN, an expert witness for Massachusetts. Age 53. Residence, 448 Riverside Drive, New York City.

Graduated—Lawrence Scientific School, Harvard University 1899, degree of S. B.

A resident of Massachusetts for 17 years.

For the past 31 years engaged continuously in engineering work. For the past 12 years as a consulting engineer on water supply and sanitary work. Office, 30 Church Street, New York City.

Previous to 1918 for 13 years an engineer for the City of New York on the development of the Catskill sources, a 600 million-gallon-per-day water supply for New York City.

Previously employed on the New York Subways and on mine and tunnel work.

Member: American Society of Civil Engineers.
American Institute of Consulting Engineers.
American Water Works Association.
New England Water Works Association.
New York Municipal Engineers.

FRANK A. BARBOUR, an expert witness for Massachusetts.

Business: Consulting Engineer, specializing in Water Supply and Sewerage, office Boston, Massachusetts.

Education: Graduate of University of New Brunswick.

Experience: After three years of railroad work became associated with the late Desmond Fitzgerald in work on the Boston water system, including investigation of additional supply.

Then for six years, at Brockton, Mass., in design and construction of sewage disposal plant—the last three years in charge of chemical laboratory at disposal plant. During this time made studies in connection with additional water supply for the city.

In 1900, with Mr. F. H. Snow, began private practice in Boston, continuing until 1906 with Mr. Snow, and since that time alone—with the exception of three years (1923-25) when Mr. G. G. Dixon was associated with him. For some ten years had a branch office at Columbus, Ohio.

Has been engaged largely in water supply and sewerage and has been retained in the investigation, design, and in the majority of cases, in the construction of some fifty water systems, and about the same number of sewerage systems this work being distributed through New England, New York, New Jersey, the middle west and Canada.

Among the water systems on which I have done work are the following:

Fall River, Mass.—Study of additional supply, reinforcement of distribution system, distribution reservoir, additional pumping equipment, the expropriation of the Lakeville Ponds, and the settlement of damages with power owners on the stream below.

New Bedford, Mass.—Consulting engineer to the New Bedford Water Board, work on additional supply, valuation of water power damages on the Nemasket River, construction of additional 60" lock joint concrete pipe intake—rate study involving valuation of system.

Lowell, Mass.—Various improvements, including construction of filtration plant, distributing reservoir, pumping station, pumps, studies of additional supply, reinforcement of distribution system.

Attleboro, Mass.—Additional supply, construction of dam, reinforcement of distribution system.

St. John, N. B.—Additional supply, dam, transmission mains, reinforcement of distribution system.

Woonsocket, R. I.—Studies of additional supply and improvement in distribution system.

Amherst, N. S.—Additional supply, dam and pumping equipment.

Peabody, Mass.—Additional supply, pumping plant, distribution reservoir.

Framingham, Mass.—Additional supply, pumping plant, distribution reservoir.

Marblehead, Mass.—Additional supply, pumping equipment, filter distribution storage and pipe system.

Reading, Mass.—Investigation of additional supply, storage, reinforcement of distribution system and investigation of probable future cost of water from Metropolitan District System.

Fredericton, N. B.—Filtration plant and reinforcement of distribution system.

Montreal, Canada.—Member of Commission to investigate structural conditions of filter plant.

City of New York—Member Special Commission on Filtration of Croton Supply.

Akron, Ohio.—Design and construction of supply, including dam, filtration plant, pumping equipment, transmission mains, distribution reservoir and reinforcement of distribution system.

In sewerage and sewage disposal, I have done work at Braintree, Maynard, Milford, North Attleboro, Needham, Hudson, Framingham, Marblehead, Taunton, Reading and Peabody, in Massachusetts: Lakewood, Mansfield, Sandusky, Cuyahoga Falls, Girard, Newark, Massillon, Wadsworth and Springfield, in Ohio: Atlantic City, Asbury Park and Monument Beach in New Jersey, Saratoga Springs in New York, West Chester, Pennsylvania.

I have also done considerable work in the developing of water supplies for and the disposal of manufacturing wastes of industries, including Goodyear Rubber Company, Goodrich Rubber Company, Columbia Chemical Company, American Glue Company, etc.

I have done considerable work in the valuation of water

powers in connection with water systems, such as those on the Cuyahoga River at Akron, Ohio.

In connection with the taking of the Lakeville Ponds by Fall River, New Bedford and Taunton, I represented the three cities in appraisal of water power damages on the Nemasket River.

I have for 30 years been engaged in work which has brought me into contact with the particular water resources involved in the present case. Thus, my work at Lowell, Milford, N. H., Laconia, N. H. and on investigation of power developments below Merrymeeting Lake, has made me familiar with the Merrimac River valley situation: early work on the Boston Water Supply and for Framingham, Reading and other adjacent communities, has given me intimate knowledge of the present Metropolitan system. During the Legislative hearings on the relative merits of the Ware-Swift and Hazen projects I represented Framingham, and thus have personal knowledge of the reactions of the legislature to these projects.

I am a member of the

American Society of Civil Engineers.
Canadian Institute of Engineers.
American Water Works Association.
New England Water Works Association (Past President).
Boston Society of Civil Engineers (Past President).
American Public Health Association.
American Society for Testing Materials.
American Society for Municipal Improvement.

I am a member of the Committee on Water Works Practice of the American Water Works Association, which supervises the work of all technical committees of that association.

WESTON E. FULLER, an expert witness for Massachusetts.

Graduate of Cornell University in 1900 with degree of C. E.

Instructor at Cornell University 1900-1902.

Resident engineer in charge of water works construction 1902-1907.

Member firm Hazen & Whipple Consulting Engineers 1908-1914.

Member firm Hazen, Whipple & Fuller Consulting Engineers 1914-1922.

Consulting Engineer 1922-date.

Professor of Civil Engineering, Swarthmore College 1922-1929.

Special Lecturer on water works Harvard University 1926.

Member American Society of Civil Engineers and American Water Works Association.

Have designed waterworks and sewers for many cities and had supervision of the construction. Some of these cities are Portland, Me.; Yonkers, Peekskill, Ogdensburg, Auburn, Poughkeepsie, Watertown, Long Beach, and Sea Cliff, New York; Miami and West Palm Beach, Florida; Springfield, Salem and Beverly, Mass.; Plainfield, Westfield, Camp Dix and Franklin Furnace, New Jersey; Palmerton, Pa.; Ottawa and Toronto, Ontario.

Have made investigation and reports on new supplies for water works and improvements to existing supplies and for improvement for sewer systems for many cities among which are, Elizabeth, Bayonne, New Brunswick, Plainfield, Paterson in N. J.; Ogdensburg, Watertown, Yonkers, Poughkeepsie, New-

burgh, Long Beach, Florida, Ottawa, Peterboro, Guelph, Ontario, Suffolk, Winchester, Newport News, Virginia; Salisbury, Maryland, Brandon, Manitoba, Piqua, Ohio, Long Branch, New Jersey.

Have also valued some thirty (30) waterworks properties, some of which are; Hackensack Water Co., Elizabethtown Water Co., Plainfield Union Water Co., Commonwealth Water Co., Tinter Manor Water Co., New York and New Jersey Water Co., Passaic Consolidated Water Co., which serves between 60 and 70 municipalities in New Jersey, Newport News Water Co., Dunham (N. C.) Water Co., Miami (Florida) Water Co., New York Interurban Water Co., Long Beach Water Co., Cortland (N. Y.) Water Co.

Have also valued a number of water power properties and water power sites; among these are Properties of the Susquehanna Power Co., at Conowongo on the Susquehanna River, Cohoes (N. Y.) Light and Power Co., several power sites of the Adirondack Power Co., ten sites on properties in the Catskill Mountains which were damaged by New York City in the development of its Catskill water supply, several power sites for the City of Providence, several power sites for the North Jersey Water District and others.

HARRISON P. EDDY, an expert witness for Massachusetts.

Graduated from the Worcester Polytechnic Institute in 1891.

Immediately entered the employ of the Worcester Sewer Department, having charge, as Superintendent, of the sewage treatment plant from the fall of 1891 for about one year. Elected by City Council of Worcester as Superintendent in charge of the Sewer Department in the fall of 1892, which position was held continuously for 15 years until the spring of 1907. Dur-

ing this period constructed by day labor all sewers and drains, approximating 100 miles in aggregate length; enlarged the chemical precipitation plant for sewage treatment; installed large sewage sludge dewatering plant; and constructed some 43 acres of intermittent sand sewage filters. Had charge of all maintenance and operation of the department, including the sewage treatment plant at which investigations and researches in stream pollution and treatment processes were carried on continually; and consulted with the Water Commissioner and City Engineer with reference to the local water supply problems.

In the spring of 1907 formed a partnership with the late Leonard Metcalf, under the firm name of Metcalf & Eddy. This partnership continued until dissolved by the death of Mr. Metcalf early in 1926, at which time a new partnership was formed with the engineers who had been taken into the former partnership and assistant engineers, the original firm name and the latter partnership being continued until the present time.

During this period of 23 years to date, have specialized in problems of water supply, water purification, stream pollution, sewage purification and industrial wastes treatment.

In 1910 and 1911, in collaboration with Messrs. John W. Alvord and the late Prof. George C. Whipple, as a commission appointed by Milwaukee, to investigate the problems of protecting the water supply derived from Lake Michigan and disposing of the municipal sewage, recommended the filtration of the water supply and the treatment of the sewage. The commission also recommended the immediate treatment of the water supply with chlorine derived from bleaching powder, this being one of the early installations for disinfection of water supplies with chlorine.

For the Metropolitan Sewerage Board of New York investigated the degree and extent of pollution of the harbor waters.

In 1911 and 1912 made a further investigation of the effect of the discharge of sewage into New York Harbor and testified before a master appointed by the U. S. Supreme Court to hear the case of New York versus New Jersey, relative to the discharge of the Passaic Valley sewage into New York harbor.

In 1912 in connection with the problem of disposing of the sewage of the city of Cincinnati, investigated the degree and extent of the pollution of the Ohio River water with reference to its use as a source of water supply by Cincinnati and other communities.

In 1916 and 1917, with George W. Fuller and the late Dr. Rudolph Hering, investigated the problem of sewage disposal for the city of Buffalo and the pollution of the Niagara River, with particular reference to its use as a source of the water supplies of communities further downstream.

From 1917 to 1921 advised the Milwaukee Sewerage Commission with reference to researches in methods of sewage treatment and the design of the sewage treatment plant, with particular reference to the cleaning of the rivers and the protection of the bathing beach waters and the municipal water supply.

In 1918 made an investigation of the problem of sewage disposal for the city of Cleveland, giving particular attention to the pollution of the waters of Lake Erie in the vicinity of the city.

Served the Sanitary District of Chicago in 1921 and 1922 on a commission comprising also Mr. George W. Fuller and Mr. T. Chalkley Hatton, appointed to report upon the lake lowering controversy in connection with which investigation and report the water supply problem was studied.

Again, assisted the District in Wisconsin et al. versus Illinois and the Sanitary District of Chicago, paying particular attention to the problem of protecting the water supply of the

city of Chicago from contamination by the sewage and industrial wastes of the city, giving consideration to methods of avoiding contamination and of purifying the water. Testified in the early hearings before the Special Master, Charles Evans Hughes, appointed by the United States Supreme Court, and again upon the re-reference of the case.

In 1925, in conjunction with Messrs. C. W. Hubbell and John H. Gregory, served on a commission to investigate and advise upon the problem of sewage disposal of the city of Detroit, in connection with which the effect of the sewage upon pollution of the Detroit River and the municipal water supply was given particular attention.

In 1925 and 1926 advised the city of Detroit with reference to the sewerage and storm water relief of the east side of the city and surrounding towns, comprising some 30 square miles, giving particular attention to the effect of the discharge of sewage and storm flows upon the easterly end of Lake St. Clair and the Detroit River, and the discharge of the storm flows in such a way as to reduce the pollution of these waters above the waterworks intake.

In 1929 made an exhaustive investigation of the pollution of Lake Ontario and tributary waters in the vicinity of Rochester, by the sewage of the city, with particular reference to the effect of the pollution upon the bathing beach waters, and advised the city with reference to improvement in its sewage treatment facilities.

During this period of nearly 40 years have de[illegible] continuously with problems relating to the effect of industrial wastes upon the waters into which they were discharged, upon their effect on the treatment of municipal sewage when mixed therewith, and the treatment of the wastes by themselves.

This experience covers almost continuous study, investigation and advice upon water supply problems involving up-

land, well, large river and Great Lake supplies, the removal of iron and oil, treatment with copper sulphate and with lime and filtration in various forms.

Have had direct charge of or supervised the operation of sewage, industrial wastes and water purification plants for many clients and am serving in this capacity at the present time.

Have served in an advisory capacity some 125 municipalities, including in addition to those hereinbefore mentioned, the cities of Boston, Cambridge, Concord (Mass.), Fitchburg, New Bedford, Springfield, Pawtucket, Hartford, Concord (N. H.), Syracuse, Schenectady, Louisville, Pittsburg, Allentown, Akron, Dayton, New Orleans, El Paso, San Antonio, Fort Wayne, Fort Worth, and Toronto, Canada.

During this experience of 40 years have been a constant student of sewage disposal and water supply problems in this country and abroad, having made several foreign trips for this purpose.

In collaboration with the late Leonard Metcalf have written "American Sewerage Practice," a three volume treatise upon sewage disposal, "Sewerage and Sewage Disposal," a textbook upon this subject, and many professional papers.

Am a member of the American Society of Civil Engineers (at present member of the Board of Direction), the American Institute of Consulting Engineers (Vice-President in 1925 and 1926), the Institution of Civil Engineers (British), the Institution of Sanitary Engineers (British), the Engineering Institute of Canada, the Boston Society of Civil Engineers (President in 1914), the American Water Works Association, the New England Water Works Association (Honorary Member), the American Public Health Association, the Society for Municipal Improvements, the American Chemical Society, and others.

GEORGE W. FULLER, an expert witness for Massachusetts.

I reside in New York City; am 61 years old; and am an engineer specializing in water supply and water purification matters, sewerage drainage and treatment works for domestic and industrial wastes. I make investigations and reports for new sources of water supply and extensions to existing works; also prepare plans and specifications and supervise the construction and operation of water supply works.

I was graduated from the Masschusetts Institute of Technology in 1890 and took special courses in bacteriology at Berlin. Then I spent about nine years in research work related to methods of purifying water and sewage from engineering, chemical and bacterial viewpoints. For about one-half of this period I was a member of the technical staff of the Massachusetts State Board of Health and during the remainder I was in charge of investigating means of purifying the muddy and polluted Ohio River water at Louisville and Cincinnati.

From May '91 to September '95 I lived at Lawrence and was employed at the experiment station there of the Massachusetts State Board of Health. I had previously been an assistant of Professor Sedgewick during the winter of 1890-91 when he was investigating typhoid epidemics in Lowell and Lawrence. I assisted in tests made whereby Lowell substituted a well water supply for the polluted Merrimac River water and Lawrence constructed filters which were put in service in September '93. During this period I also assisted in securing data for the State Board in reference to its 1895 report on the Metropolitan Water Supply.

Following my four years in Louisville and Cincinnati, I opened an office in New York and have since been engaged in private engineering practice. I was a member of the firm of Hering and Fuller 1901-1911 and have been a member of

Fuller and McClintock since 1916. During the past thirty year, I and my organization have advised some 150 of the larger cities and towns in this country on matters of water supply and about an equal number in matters of sewerage and sewage treatment. We have made valuations of some sixty water works plants and since 1917 I have devoted a substantial portion of my time to valuation matters related to street railway properties. Since 1920 I have been a member of the Valuation Board of the Mitten Management which operates the properties of the Philadelphia Rapid Transit Co. and the International Railway Co., operating in the Buffalo district and each side of the Niagara River.

I was a member of a board of engineers at New Orleans 1900-09 during which the city built new systems of water works, sewerage and drainage. I have made investigations and reports on new water supply projects for Springfield, Mass., Montreal, Albany, New York, Philadelphia, Pa., Jacksonville, Florida, Memphis, Tenn., Toledo, Ohio, Grand Rapids and Battle Creek, Michigan, St. Louis and Kansas City, Missouri, Denver, Colorado, etc.

I particularly had to do with the selection of type, design and supervision of construction and operation of numerous sizable water purification plants such as those at Louisville, Cincinnati, Little Falls, (East Jersey Water Co.) Hackensack Water Co. plant at New Milford, New Jersey, Philadelphia, Baltimore, Washington, Richmond, Memphis, Dallas, New Orleans, Kansas City, Minneapolis, Buffalo, Montreal, and many other smaller plants.

From 1906 to date I have been a consultant to the New York Board of Water Supply in matters related to quality of water, have served Jersey City as consultant and have made several investigations into programs for securing better upland sources of supply for Philadelphia. On matters of sewerage and sewage disposal, I have made investigations and reports at

New Orleans, Atlanta, Columbus, Ohio, Indianapolis, Toledo, Reading, Pa., Passaic Valley in New Jersey and for the city of New York in 1913 and again in 1928. I am now engaged in the design of a sewage treatment plant for New York City having a capacity of 180 m.g.d. and located on Ward's Island in East River.

At Chicago, I have been connected with the local drainage canal project for twenty-five years. I testified in 1903-04 in the Missouri case; in the federal suit in 1913 and in the so-called Wisconsin suit, now pending before the U. S. Supreme Court, in 1927. In 1924-25 I was Chairman of a board of twenty-eight engineers which investigated and reported upon a program for the sanitary district of Chicago. I also reported on this subject to the International Deep Water Commission in 1906. From 1914-17 I advised the International Joint Commission in matters of policy related to the control of pollution of international boundary waters in accordance with the provisions of the 1909 Treaty between Great Britain and the United States.

I was consulting Engineer 1927-28 to the New Jersey State Water Policy Commission and assisted in drafting a tri-state pact for consideration by the states of New York, New Jersey and Pennsylvania for the allocation of the waters of the Delaware River.

I am now engineer for the North Jersey District Water Commission in charge of the Wanaque Aqueduct construction for delivering upland water to Newark and associated cities.

As to the disturbance of water supplies, even where filters are installed, by industrial wastes we have had experience with wood pulp wastes at Richmond, Virginia; wood alcohol wastes at Warren, Pa.; and mine water drainage at the Mountain Spring Water Company of the Pennsylvania Railroad; phenol wastes at Milwaukee, Chicago, etc., etc.

I have had considerable to do with joint undertakings for groups of municipalities in matters of water supply, sewerage, and the disposal of industrial and domestic wastes. I am familiar with difficulties in finding practical solutions for these joint undertakings and the complications which relate to interstate and international jurisdictions. I have considered these matters as to history of the development of administrative practices in Europe for control of pollution of water supplies in the course of ten or more visits to Europe.

I am author of "Water Purification at Louisville", 1898; "Sewage Disposal", 1912; and in connection with my partner, J. R. McClintock, "Solving Sewage Problems", 1926.

I am past president of the American Water Works Association and the American Public Health Association.

J. WALDO SMITH, an expert witness for Massachusetts (2166) was graduated from Massachusetts Institute of Technology in 1886.

Has received the honorary degree of Doctor of Engineering from the Stevens Institute of Technology and the degree of Doctor of Science from Columbia University.

Awarded the John Fritz medal of the National Engineering Societies for "achievement as engineer in providing the City of New York with a supply of water".

The Washington Award for pre-eminent services in promoting the public welfare was conferred on him by the Western Society of Engineers in 1925, "for the rare combination of vision, technical skill, administrative ability and courageous leadership in engineering."

Is consulting engineer to the Board of Water Supply of the City of New York and to the Metropolitan District Water Supply Commission of Boston.

Has acted as consulting engineer in connection with the water supplies of Providence, Rhode Island; Kingston, New York; Catskill, N. Y.; Philadelphia, Pennsylvania; Ashville, North Carolina; Government of Cuba with particular reference to Havana; Kansas City, Missouri; Vancouver, B. C.; San Francisco, California; East Bay Municipal Utility District, Oakland, California and other places.

Was consulting engineer on the Moffatt Tunnel, Denver, Colorado.

Was consulting engineer to the Massachusetts Joint Board which in 1922 reported relative to the water supply needs and resources of the Commonwealth (Complainant's Exhibit No. 1).

In 1903 he was appointed Chief Engineer of the Aqueduct Commissioners of the City of New York.

In 1905 he was appointed Chief Engineer of the Board of Water Supply of the City of New York, which position he held until 1922, since which time he has been consulting engineer to that Board. The Catskill Supply developed by this Board was designed and constructed under his leadership at a cost of about $180,000,000, during a period of about 10 years.

JOSEPH A. MC CARTHY, an expert witness for Massachusetts (1765) assistant at Lawrence Experiment Station of Massachusetts Department of Public Health.

He has been connected with this station since 1910 except during the war. The Lawrence Experiment Station operates

experimental water and sewerage plants of all kinds for the solving of problems of water and sewerage purification encountered by cities, towns, corporations and individuals of the Commonwealth.

CHARLES D. HOWARD, an expert witness for Massachusetts (1643) chief of the Division of Chemistry and Sanitation, New Hampshire Board of Health.

A graduate of Worcester Polytechnic Institute with a degree in chemistry in 1893.

1893 to 1895 was private assistant to Dr. Walcott Gibbs, Newport, R. I., and to Professor Kinnicutt of Worcester Polytechnic Institute.

1895 to 1898, assistant chemist at the State of New Hampshire Experiment Station.

1898 to 1905 was assistant chemist and later associate chemist at the West Virginia University Experiment Station, where he was identified with an investigation of the pollution of the Monongahela River.

Since 1905 he has occupied his present position.

WILLIAM F. UHL, a consulting engineer, educated at Michigan State College, and a member of the organization Charles T. Main, Incorporated, for over twenty years. This organization, which has been in business under the leadership of Mr. Charles T. Main for thirty-five years, does a general engineering practice, including the designing and supervision of construction of steam, electric and water power plants, and of industrial plants and textile mills. Some of the more import-

ant power developments for which it has acted as consulting engineer or which were designed and supervised by it include the hydro-electric developments of the Montana Power Co., in Montana, since 1909; those of the Georgia Railway and Power Co. over a period of about twelve years; the Conewingo development on the Susquehanna River; and the Fifteen Mile Falls development of the New England Power Company on the Connecticut River. Many other smaller power developments throughout New England and other states, like that of the Rockland Light and Power Company in New York State have been designed and supervised also. Charles T. Main, Incorporated, has acted as consulting engineer for some of the lessees of the water power companies at both Lowell and Lawrence on the Merrimac River and for the Holyoke Water Power Company at Holyoke on the Connecticut River.

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